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MODERN ASSAYING

A CONCISE TREATISE

DESCRIBING LATEST METHODS AND APPLIANCES

By

J. REGINALD SMITH

Edited by

F. W. BRAUN

WITH 80 ILLUSTRATIONS

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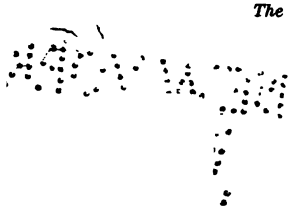

TO THE BUSY MAN

WHOSE TIME HAS BEEN AND IS NOW SO OCCUPIED WITH OTHER DUTIES THAT IT IS IMPOSSIBLE FOR HIM TO DEVOTE HIS ATTENTION TO TECHNICAL WORKS ON ASSAYING; AND TO THE MAN WHO DESIRES AN INSIGHT INTO THE PRACTICAL METHODS OF ASSAYING IN THE SHORTEST TIME POSSIBLE, THIS BOOK IS DEDICATED.

THE AUTHOR

PREFACE

There is in truth no royal road to learning, yet there are obstacles that may be cleared away and paths that may be straightened, whereby the student and the over-worked man of affairs may pursue the journey with the smallest amount of difficulty, and the fewest stumbling blocks.

To such, therefore, this little treatise on assaying and precious metals is addressed.

It is not intended to be an exhaustive exposition of the subject nor to take the place of the many excellent and comprehensive technical works on assaying, but rather to present in a concise, intelligible, and non-technical manner the science and methods for the assay of precious metals, so that the reader may in the shortest possible time acquire sufficient knowledge and dexterity of manipulation to enable him to follow out practical work. When this is done, further advancement will be restricted only by the grasp and ambition of the student. Having mastered the first groundwork, he will soon gain familiarity with the rudiments of the science and the handling of the apparatus.

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INTRODUCTORY

The art of assaying is a branch of analytical chemistry in connection with mining and metallurgy. Its object is to obtain the value of a stated quantity (usually an avoirdupois ton) by determining the value of a small representative sample.

There are two methods: the "dry" and the "wet." By the "dry" method is meant the assaying or producing of chemical reaction by furnace melting or smelting the precious metals out of the ore sample by means of heat and reducing fluxes. This method is accurate in the case of gold and silver ores that are not very refractory, but with many other metals the "wet" method is generally adopted to obtain greater accuracy.

There are several classes of "wet" methods, such as precipitating by electrolysis, the colorimetric, the gravimetric, the volumetric, etc., but as volumetric assays can be performed the quickest and most simply, the purpose of this book will be best attained by presenting only this system of the "wet" method, and the improved Guess-Haultain electrolytic method for copper and lead.

MODERN ASSAYING

CHAPTER I.

SELECTION AND PREPARATION OF SAMPLE.

"*A*" Selecting Sample from Bulk.—"*B*" Crushing.—"*C*" Quartering.—"*D*" Pulverizing or Pulping.

"*A*" *Selecting Sample from Bulk.*—The first step in assaying is to obtain a sample, and it is all-important that the portion selected should be representative of the entire quantity (Fig. 1). No special pieces should be picked from the bulk, but the desired quantity is taken indiscriminately from the entire original parcel.

"*B*" *Crushing.*—Grind or break the entire quantity of the sample to as near as possible a uniform size. This can be done in two ways. The old method was to pound it up in an iron mortar, but now small hand crushers have been placed on the market superseding this old way. The latest improvements in these are called the Simplex, Chipmunk, and Lightning Crushers (Fig. 2). They are light portable machines which will reduce a sample to fragments about the size of peas with one crushing. This will enable the operator

to secure an accurate division of the sample. The Chipmunk Crusher (Figures 2*a* and 2*b*) is now recognized as the standard laboratory machine. It is made with a steel frame and iron jaws and fittings, which give it great strength. It is made in various sizes, having capacities from 300 pounds to 800 pounds per hour, reducing the rock from about 2 inches in size to ¼ mesh. It can be operated by either hand or power. The front jaw can be readily removed, which exposes all of the crushing chamber for thorough cleaning.

FIG. 1—Sack containing ore to be crushed, quartered and assayed.

"C" Quartering.—Now thoroughly mix by stirring and rolling the crushed ore on a large mixing sheet from end to end of the sheet and then from side to side. Divide into four equal divisions by making a line through the centre of the entire sample, and then another line through the centre of the sample at right angles to the first line. Take the two divisions that are diagonally opposite and discard the balance. Repeat this operation after thoroughly remixing the diagonal

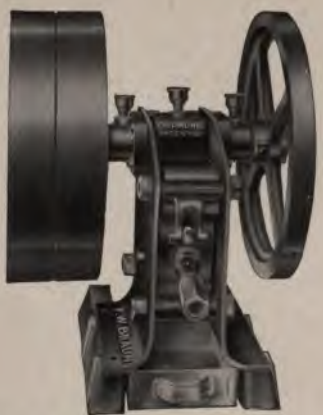

FIG. 2*a*—Chipmunk Crusher (closed).

FIG. 2*b*—Chipmunk Crusher (open for cleaning).

FIG. 24—Mouth Blowpipe, Automatic.

portions, and continue doing so until the final remaining two diagonally opposite divisions make such a quantity as will furnish pulp (when the ore has been reduced to a powder it is usually called "pulp") for several assays of the same sample. Care must be used in this operation as the accuracy of the assay depends largely on this.

FIG. 2—Crushing ore with Simplex Crusher.

An automatic sampler has been invented (Fig. 3 and 3*a*) called the Umpire Ore Sampler. This machine guarantees an absolutely accurate dividing of the sample, and is highly recommended where any quantity of work is to be done. Each bucket is divided into four equal sections, two of which are closed and two open. Thus if 16 pounds of ore are

put into the hopper and the machine operated, 8 pounds will remain in the upper bucket, 4 pounds pass to the lower bucket, and 4 pounds, or one-fourth of the whole amount will go into the receptacle at the bottom. A second feeding of the 4 pound portion obtained in the first operation would result in a 1

FIG. 3—Umpire Automatic Ore Sampler.

pound sample or one-sixteenth of the total amount. It is advisable to retain a large enough sample to make from four to six assays in case of necessity.

"D" Pulverizing or Pulping.—It is now necessary to reduce the quartered or remaining sample to a fine powder usually called "pulp." This is done by grinding the sample on a flat iron plate with an iron rubber, both of which have smooth surfaces, called a "buck-

FIG. 3a—Umpire Automatic Ore Sampler, power (sectional view).

FIG. 4—Bucking Board and Muller.

FIG. 5—Sample Grinder (closed)

FIG. 5*a*—Sample Grinder (open for cleaning).

FIG. 5*b*—Braun Pulverizer (closed)

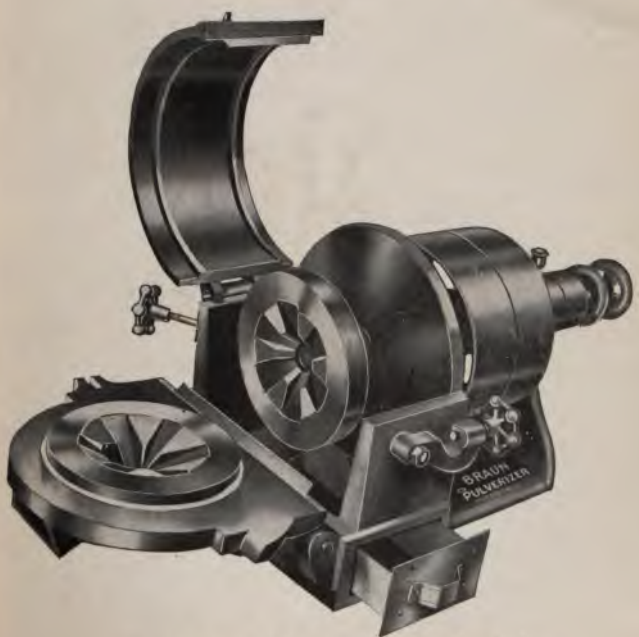

FIG. 5*c*—Braun Pulverizer (open for cleaning).

ing board and muller" (Fig. 4). This operation must be done very carefully to avoid losing any of the sample. For this work more modern appliances have been invented. For hand power a Sample Grinder (Fig. 5 and 5*a*) is the most convenient. This machine replaces the old fashioned bucking board. It consists of two grinding plates mounted in horizontal position and it is between these plates that the pulverizing is done. The lower grinding plate is rapidly revolved by a fly wheel with handle, geared to the vertical shaft. The material is discharged into a removable dust proof bucket. Any desired degree of fineness required for assaying may be obtained with one feeding. A 4 ounce sample of ordinary granite rock can be reduced in this machine to 80 mesh in 2½ minutes. Where power is available the Braun Pulverizer (Figures 5*b* and 5*c*) is recommended. The grinding plates in this machine are mounted in a vertical position, and the material is fed through a spout in the door. The discharge is regulated by a hand wheel at the end of the shaft. The paramount features are, (1) that an entire sample can be pulverized with one grinding to any desired mesh; (2) the ease with which all the interior portions are exposed for thorough cleaning; (3) the rapidity with which samples are pulverized, it being possible to grind one pound per minute to 100 mesh. It requires one horse power to

operate. Use not less than a 60 mesh or preferably an 80 mesh sieve for pulp samples (Fig. 6). The idea of pulverizing is not merely to disintegrate the ore so as to expose the minute particles to the action of the

FIG. 6—Screening pulp to insure all being of desired degree of fineness; coarse material must be reground until it passes through sieve.

flux, but more especially to divide the free gold particles present so uniformly that in mixing the sample no one portion will contain coarser and heavier particles of gold than another.

CHAPTER II.

FIRE ASSAY FOR GOLD AND SILVER.

"*A*" Classification of Ores.—"*B*" Sulphide Ores.—"*C*" Fluxing.—"*D*" Furnaces and Melting.—"*E*" Cupels and Cupellation.—"*F*" Weighing and Quartation.—"*G*" Parting.—"*H*" Coarse Gold in Assay Samples.

"*A*" *Classification of Ores.*—In fluxing ore for gold and silver, first determine the nature of the sample submitted for assay. Three different classifications may be made in the preliminary examination of ores; first, pure quartz (very glassy or vitreous); second, no quartz (plastic and free from grit); third, a mixture of these two extremes which may be assumed to be the average as to siliciousness. Approximately knowing the nature of the sample as to these proportions, add such fluxes as will modify either extreme to an average mixture. For example, in pure quartz omit the silica or glass that the flux would otherwise contain as the ore has already a sufficiency. If the ore is free of silica, mix in more silica or glass than otherwise would be added to an average ore.

This preliminary examination is all-important, as by its aid the proper additions are made whereby the gangue or waste is suspended in the form of slag, allowing the lead to alloy with and gather all the gold

and silver contained in the sample. Ores containing a large excess of silica require the addition of some deoxidizing or basic flux, or of some material of a basic and reducing nature to counteract the too oxidizing effect of the acid silica flux already in the ore; more litharge and argol or flour will remedy such a case. Experience only will enable the operator to estimate the proper amount of basic and reducing flux necessary to bring down a proper sized lead button without running what is called a preliminary assay to determine the amount of the reducing agent already in the ore.

Experience shows that more satisfactory results are obtained by bringing down a larger lead button than some writers consider necessary. Ordinarily a 20 gram lead button is about right, but with ores containing metals that volatilize at low temperatures a larger lead button should be obtained. This applies to telluride ores, and also to zinc and antimony ores. In such ores the size of the button may be increased by adding more litharge and reducing agent to the flux mixed with the ore.

"*B*" *Sulphide Ores.*—Ores containing much sulphur or sulphurets should be roasted preliminary to fluxing for crucible assay. This is done in the muffle after a known quantity, say one or two assay tons (page 65 for definition of assay ton), is carefully weighed

and put in a roasting dish (Fig. 7). The ore should be stirred with a stiff wire or light iron rod frequently during the roasting operation to prevent the ore from caking, and to give the sulphur in the ore a chance to

FIG. 7—Roasting dishes.

burn out. This operation takes but a few minutes, and as soon as the ore is cool it may be scraped out of the dish, ground lightly in a wedgewood mortar (Fig. 8) to break up any crust formed in roasting, and

FIG. 8—Wedgewood mortar

fluxed in the same manner as any other ore. Roasting is not necessary unless the sample contains a large quantity of sulphurets. Ores containing but a small amount of sulphurets may be desulphurized during

the melting by putting several large iron wire nails in the crucible (Fig. 9) with the charge. The nails may be left in the crucible until the charge is molten, and then carefully removed before pouring the melt into

FIG. 9—Fire clay crucibles.

the pouring mold (Fig. 10). The excess of sulphur unites with the iron, forming a matte (sulphide of iron). Let the slag be very fluid and the lead will all run out of the crucible when poured into a mold. Ores containing no sulphurets need no nails during the melting nor any preliminary treatment.

FIG. 10—Pouring mold.

"C" Fluxing.—If ores are of reasonably good value, say from $10.00 gold value per ton upward, use charge of 1 assay ton, and if of a lower grade take a charge of 2 assay tons, using a larger crucible. This is so that in the case of a low grade ore more gold may be obtained to weigh. Thoroughly mix the pulp

sample, and weigh on the pulp balance (Fig. 11) 1 or 2 assay tons, as judgment may dictate. Place the flux (see page 68 on the subject of fluxes) in the crucible (Fig. 9), carefully transfer the pulp to the crucible and thoroughly mix the flux with the sample, using a 5 or 6″

Fig. 11—Weighing pulp.

spatula (Fig. 11*a*) for mixing. This mixing is important as it exposes all the minute particles of the fluxes.

The crucible commercially known as Battersea "B" or 20 gram size will be found convenient for use when 1 assay ton of ore is taken; size "F" or 30 gram when 2 assay tons are used. Select crucibles of such sizes as will contain 1 or 2 assay tons, as the case may be, together with the necessary amount of flux.

"D" Furnaces and Melting.—The next operation is melting in the furnace the charge placed in the crucible. There are many kinds of furnaces using various materials for heating, such as coal, coke, gas, and gasoline. Those now most frequently used are gasoline furnaces.

Fig. 12*a* represents one of the latest gasoline furnaces called the Cary Combination Furnace. The main feature of this furnace is that both operations of melting and cupelling may be carried on simultaneously at the

FIG. 11*a*—Spatula

required degree of heat. By use of the Cary Burner shown in Fig. 12*b* a great saving is effected in the consumption of gasoline, and the loud pulsating noise, which was objectionable in the older styles of gasoline burners, has been overcome to a very great extent. Perfect combustion is obtained in this furnace at a minimum cost. By working with gasoline under an air pressure of 25 to 30 pounds as shown on the gauge, a charge may be properly reduced in a gasoline furnace in from fifteen to twenty-five minutes.

The new type of Combination Furnace, which is known as the Braun Rotary Flame Combination

urnace, is shown in Figure 12*c*. The muffle is placed rectly over the melting chamber, thereby allowing large crucible capacity. The flame enters the centre,

FIG. 12—Placing the crucibles in the furnace.

rikes a special dividing brick and is whirled around e crucibles. Varied temperatures are obtained, lowing of the proper annealling of all crucibles. he Braun Gas Burner is shown, which consumes dinary illuminating gas. A Combination Motor and

Blower shown in the same illustration is necessary to operate this Burner. This can be attached to the regular lighting circuit.

Special Crucible and Muffle Furnaces are shown in Figures 12*d* and 12*e*, as some operators choose to use these types in preference to the Combination Furnaces.

FIG. 13—Pouring melted charge into conical shaped mold.

Marvel Burner, Figure 12*f*, can be operated with either crude oil or distillate, and is used by assayers who are unable to obtain gasoline for fuel.

Some ores reduce more readily than others, and the melting time consequently varies and must be left to the judgment of the operator. When the charge is properly smelted all bubbling or boiling will

FIG. 12*a*—No. 30 Combination Furnace Outfit with Cary Burner.

FIG. 12*b*—Cary Burner

FIG. 12*f*—Marvel Burner

FIG. 12*g*—Gas Burner.

have subsided, and the contents of the crucible will be perfectly liquid and still. Pour quickly into a previously warmed conical mold (Fig. 13) called a "pouring mold" and allow to cool. All the lead will be found to have settled, and this lead which is called the "button" will contain all the precious metals in the sample, leaving all the base metals and silica in the form of

FIG. 14—Breaking slag away from lead button.

slag at the top of the mold. Hammer the button free from slag and then into a square shape (Fig. 14).

"E" Cupels and Cupellation.—Cupels (Fig. 15), are non-combustible dishes made of compressed bone ash. By the old method they were made with a hand mold (Fig. 16) consisting of a die and plunger to form the cupel. The die is filled with moist bone ash and

the plunger struck with a mallet or hammer compressing the bone ash to form the cupel. It is very essential that the cupel be solidly made (although not too hard) and of uniform density, otherwise it will split when heated and values be lost during cupellation. When using the hand mold this is a difficult matter, and it is very slow and tedious.

FIG. 15—Cupel.

Several types of Cupel Machines are now made which have an arrangement of levers whereby the pressure is equal to twenty times the applied power. The Braun Automatic Cupel Machine (Fig. 17) will automatically fill the mold each time with the required quantity of bone ash, which is then compressed by one movement of a hand lever, thus insuring a perfect cupel of uniform density. This machine has a capacity of 600 perfect cupels an hour, and a boy can operate it. This type has interchangeable discs and dies for making five different sizes of cupels. The table pattern (Fig. 17*a*) requires the mold to be filled by hand. It has interchangeable dies and plungers for making three sizes of

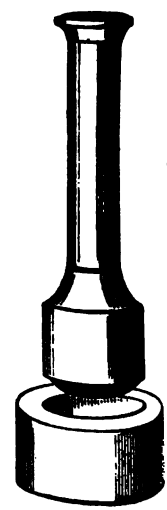

FIG. 16—Cupel mold.

pels. The wall pattern (Fig. 17*b*) requires a separate machine for each size cupel. It is necessary to ed it by hand. A suitable shelf is furnished on ıich the bone ash is placed.

A stock of cupels should always be kept on hand they require slow and gradual drying before using,

FIG. 17—Braun automatic cupel machine.

herwise they will crack when subjected to heat. ıpels made by Braun machines do not require as ıch moisture as hand-made cupels and consequently y faster. Machine-made cupels are also one solid mass, ing pressed with one movement, and are not in lay- as are hand-made cupels, the result of several blows a mallet.

Cupellation is the next step; have the muffle at a bright red heat and put in it enough cupels with the cupel tongs (Fig. 18) to hold the lead buttons. Allow the cupels ample time to heat to the temperature of the muffle before using. It is a good plan to place the cupels in the muffle at the time of first heating the furnace, thus heating the muffle and cupel together. If the cupel is not at a proper heat, as soon as the button becomes molten it will sputter and spurt out of the cupel and all previous labor is wasted. Examine the cupels after they are hot to see if they are cracked anywhere; discard the cracked ones and replace with

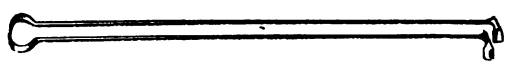

FIG. 18—Cupel tongs.

new cupels. After the cupels are sufficiently heated, put in the buttons by means of the cupel tongs (Fig. 19); place the plug in the muffle and leave it in until the buttons are brightly molten. Then remove the plug to admit fresh air for oxidizing purposes.

The Cary Furnace is so constructed that the lead fumes and vitiated air pass out of the back end of the muffle and up the main flue of the furnace. The cupellation is finished when the resulting gold and silver bead sets or solidifies and oxidation ceases. The gold bead sets in nearly a perfect sphere, and the silver bead sets in a hemispherical form. Do not remove

FIG. 17*a*—Table Cupel Machine.

FIG. 17*b*—Wall Cupel Machine.

the cupel as soon as the play of color ceases, but allow it to remain in the muffle from forty to sixty seconds to expel thoroughly any remaining lead. Cover the

FIG. 19—Placing the lead buttons in the cupels.

cupel containing the set button with a hot cupel, and remove from the furnace, placing it on a tray (Fig. 20). This covering of the cupel with another one that has been heated prevents the button from cooling too suddenly and sprouting and spitting. The button is said

to have "frozen" when by reason of insufficient heat or the presence of some base metal such as copper, it solidifies. The frozen button is easily distinguished from the set button by its lustreless appearance and uneven surface. The bead that has set properly is

Fig. 20—Iron cupel tray.

symmetrical and presents a bright surface. The remedy for the frozen button is to roll up a piece of lead foil, about 5 grams, and drop it into the cupel with the frozen button. Insert the muffle plug and allow it to become molten again, when the plug may be removed.

Fig. 21—Bead forceps.

"F" Weighing and Quartation.—After cupellation remove the bead from the cupel with a pair of forceps (Fig. 21) and clean it of adhering bone ash by brushing with a stiff button brush (Fig. 22) while it is held

in the forceps. Weigh the bead carefully in the button balance (Fig. 23) and enter the weight on a card which is placed with the cupel. Judgment is now required to determine whether or not the button will part, that is, whether there is enough silver present in the bead to allow the nitric acid to act upon it. For the bead to part properly there should be 3 parts of silver to 1 part of gold. A bead containing too little silver would not part because the gold would protect the

FIG. 22—Button brush.

silver from the acids. Silver foil need not be accurately weighed as it is added to the bead that needs alloying. It is immaterial how much silver is used, but enough should be added to allow partition. If the bead is very spherical and rolls readily in the scale pan, it is safe to assume that there is not enough silver present for parting. If the bead is yellow the same condition obviously exists. In this case the bead must be alloyed and enough silver added to make 3 parts or more of silver to 1 of gold. The alloying is best done with the mouth blowpipe (Fig. 24). Make a small excavation in a piece of assayers' charcoal and place the bead therein. Add as small a piece of silver as will suffice, and fuse the bead and the silver thoroughly together

with the blowpipe and Bunsen burner (Fig. 25) or alcohol lamp. This must be done with extreme caution as small beads are easily blown out of the charcoal and lost. Fusion must also be so complete as to make a thorough mixture of the bead and silver or the acid partition will not be perfect.

FIG. 23—Weighing bead on button balance.

Another method of alloying is to wrap the bead and a piece of silver in a small piece of chemically pure lead foil and cupel together in the muffle. This is tedious and unnecessary where the first method is carefully followed. When the silver value is to be ignored the best way to alloy is to throw a piece of chemically pure silver into the crucible with the melt

which is called alloying in the crucible. If the alloying is not done at this stage it may yet be done by placing the silver with the lead button in the cupel, although this is not advised.

FIG. 25—Fusing assay bead and silver foil, called "quartation."

"G" Parting.—For parting or removing the silver use porcelain capsules or cups 1½ inches deep by the same diameter (Fig. 26). Put the bead to be parted in the capsule, and add three or four times as much diluted chemically pure nitric acid as is needed to cover the bead. Set the capsule on the sand bath (Fig. 27) and apply a gentle heat. Partition is complete when the silver is dissolved and the red nitrous

oxide fumes cease. The acid will become very reddish while giving off these fumes, but will finally clear again when partition is finished. Any gold present will appear as a brown powder and the silver will be in solution as silver nitrate. Pour off the acid from the capsule and wash the gold in the capsule several times with warm distilled water. After carefully washing the gold drain the capsule as much as possible and dry in a sand bath. This drying operation must be performed very carefully, as otherwise the

FIG. 26—Porcelain capsule.

vaporizing moisture will spurt the gold out of the cup. When the capsule is thoroughly dry it is well to brighten the gold by holding the capsule with a pair of forceps or small tongs in the flame of an alcohol lamp or Bunsen burner until it is red hot (Fig. 28). Then cool and remove the gold from the capsule to the scale pan to be weighed. The weight of the bead before parting represents the weight of the gold and silver. The weight of the silver is now determined by deducting the weight of the gold from that of the gold and silver.

"H" Coarse Gold in Assay Sample.—In case a sample contains coarse gold that cannot be ground

so as to pass through the screen, it must be gathered together, wrapped in chemically pure lead foil, and cupelled. After cupellation weigh the bead, and this weight will be the weight of the gold and silver combined. Add sufficient silver to the bead so that when

FIG. 27—Parting porcelain capsules in sand bath over small kerosene stove.

cupelled it will contain at least three times as much silver as gold. Wrap the bead and the requisite amount of silver in chemically pure lead foil and cupel them together. Part the resulting bead as in ordinary partition and weigh the resulting gold.

The amount of gold and silver in the coarse gold

is now known, and must be apportioned to the entir amount of pulp from which it was extracted; for ex ample, had the entire amount of pulp been 10 assa tons the amount obtained by assaying an assay to

FIG. 28—Brightening gold by holding capsule in flame.

of the pulp would be entitled to the addition of 1/1(part of the amount of gold and silver that did pas the screen.

If the original weight of the entire amount of pul from which the coarse gold was separately assayec was 10 assay tons, having a value of $20.00 per to gold, and the gold recovered from the coarse meta

weighed 10 milligrams, by dividing the 10 milligrams by the total number of assay tons of the pulp, that is 10, this would leave 1 milligram in weight of gold to be added to each assay ton of the original amount of pulp. For example, the assay value of the fine pulp having been found to be $20.00, and the proportion of coarse gold to each assay ton of pulp 1 milligram or $20.67, then the total value per ton of ore in gold would be equal to $20.00 plus $20.67 or $40.67.

Silver values fluctuate and may be figured at the ruling market price per ounce. Silver value is found by subtracting the gold weight from the gold and silver weight, giving the silver weight, and from this weight the silver value is figured.

CHAPTER III.

SCORIFICATION ASSAY.

"*A*" Definition of Term "Scorification."—"*B*" When Employed.—"*C*" Usual Charge.—"*D*" Melting.—"*E*" Pouring.

"*A*" *Definition of Term "Scorification."*—Scorification may be defined as a reduction and a partial or preliminary cupellation successively performed in the same container without removal of the container from the muffle until volatilization is stopped by the slag entirely covering the charge.

"*B*" *When Employed.*—Scorification is the proper method of assaying copper mattes. It is also a good practice to first scorify, before cupelling, a lead button which has been reduced by crucible assay, and which is brittle or contains much copper or other bases. In doing this it will be necessary to add a small quantity of chemically pure test lead.

Assay by scorification is very satisfactory for base ores containing a large proportion of silver. The lead buttons from ores containing much copper or ores containing tin or nickel are best prepared for cupellation by preliminary scorification. Owing to the small amount of ore reduced (generally 1/10 of an assay ton) scorification is not suitable for low grade gold ores.

"C" Usual Charge.—To scorify ordinary ores, take 1/10 of an assay ton (0.1) of ore, mix with 20 grams of chemically pure granulated test lead, and add on top of the mixed charge about 20 grams more of test lead. Sprinkle over the lead about 0.3 gram of borax glass. Use 2″ or 2½″ scorifiers (Fig. 29). The size of the scorifier selected depends on whether 1/10 or 2/10 of an assay ton of ore is to constitute the ore charge.

FIG. 29—Scorifier.

"D" Melting.—Place the scorifier containing the prepared charge in the muffle, using scorifier tongs (Fig. 30), close the muffle and leave closed until the contents of the scorifier are thoroughly reduced. In a hot muffle this will probably take fifteen minutes. When they are properly reduced remove the muffle plug to admit air for oxidizing purposes. The ore gangue will appear as a ring of slag close around the edge of the scorifier, and this ring, as the volatilization of the lead and other bases progresses, will gradually converge to the center of the scorifier until finally the slag will cover the entire surface. All volatilization will cease when this occurs, as the slag excludes the air from the lead. Care must be taken not to have the muffle too hot nor to allow the charge to oxidize too quickly, as in this event some of the silver values will be carried away with the fumes.

"E" Pouring.—Pour the contents of the scorifier into a pouring mold (Fig. 31) and when cool enough hammer the lead button free of slag. The button may now be cupelled if not too large or too brittle, and the bead may be weighed as in a crucible assay (Chapter II). If the lead button is hard and brittle rescorify by placing it in the same scorifier. Cover with test

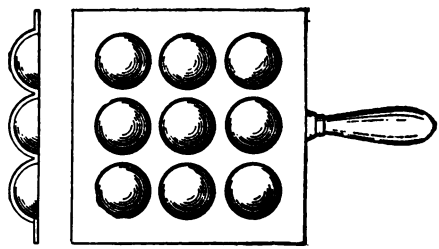

FIG. 31—Pouring mold for scorification assay.

lead, and sprinkle on top of all a small amount of borax glass (which will help as a flux). This rescorification is performed in exactly the same manner as the original process.

Rescorification may be performed in the original scorifier provided it is not weakened or too much corroded. The charge should be very fluid when poured, and it is advisable to close the muffle and raise the heat for a few minutes before pouring the contents of the scorifier into the mold.

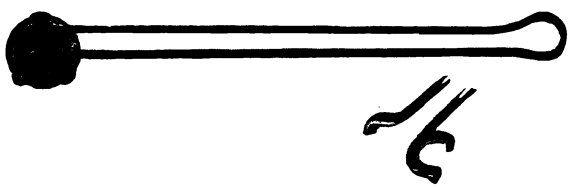

FIG. 30—Scorifier Tongs.

CHAPTER IV.

ASSAY OF GOLD BULLION.

"*A*" Drilling Sample.—"*B*" Gold and Silver Fineness.—"*C*" Weighing Sample Drillings and Quartation.—"*D*" Cupellation.—"*E*" Rolling Coronets and Annealing.—"*F*" Parting.—"*G*" Calculating Results.—"*H*" To Determine the Silver Fineness or Percentage of Silver in the Gold Bullion.

"*A*" *Drilling Sample.*—Bullion submitted for assay is usually brought in the form of bars, bricks, slugs or buttons, and a sample of bullion in this form is best obtained by drilling into the brick or slug with a small bit 3/16″ in diameter (Fig. 32). Drill enough so that the shavings or drillings will yield material for at least four assays of an original weight of from 300 to 500 milligrams. When extra care is observed in bullion assaying a certain amount of sample is taken (say 0.5 or 1.0 gram exactly weighed) and the check samples are all of the same weight as the original. The object of this is to make the check and original assays under exactly the same conditions. There is a slight silver loss through volatilization, and most technical works on assaying give tables showing the percentage of loss by volatilization. It is useless to go into this matter in a brief treatise intended merely for beginners and for others who prefer rapid methods with

reasonable accuracy. In case the bullion is very base a larger quantity of the original sample should be taken so that after alloying, cupellation, and partition, the fine gold obtained will be sufficient to weigh.

FIG. 32—Drilling out sample of bullion brick.

"B" Gold and Silver Fineness.—The percentage of gold in bullion is described as so many thousandths "fine," and is written decimally. Percentage of silver in bullion is expressed in the same manner, and is called silver fineness. A bar containing 900 parts of

gold to the 1000 would be gold fine 900, and providing the other parts were silver, the latter would be expressed as silver fine 100.

"C" Weighing Sample Drillings and Quartation.—Knowing the bar to be of a fineness in excess of 600 (see page 72, touch stone and test needles), take drillings amounting to from 300 to 500 milligrams carefully weighed on a button scale (Fig. 23, page 38) and make a weight record on a card of the number of milligrams and fraction thereof expressed decimally. This card should accompany the assay throughout its various stages. Assuming the bar from which the sample was taken to be from 600 to 800 gold fine, add silver foil so that after cupellation there will be in the bead approximately three times as much silver as there is gold. Assuming a sample weighing 300 milligrams 700 gold fine, the amount of gold present would then be .700 × 300 or 210 milligrams, and the silver to be added would be 210 × 3 or 630 milligrams. The reason for alloying or adding this amount of silver is that after cupellation the bead of gold and silver may be rolled out into a thin strip.

In order to make a perfect separation of the gold and silver it is necessary that the strip (which, after being bent or coiled, is termed a "coronet") should contain at least 2½ parts of silver to each part of gold. It would be difficult to part the silver from the coronet

without breaking it up should it contain more than 3 parts of silver to each part of gold.

"*D*" *Cupellation.*—Having added the required quantity of pure silver to the sample as above described, tear off a strip of chemically pure lead foil about 7 inches long, and fold it end to end, making the sheet of lead double the original thickness and about square. Enclose the weighed sample and the added silver in this sheet of lead by carefully folding the lead over the sample; or form the double sheet of lead into a cornucopia, placing the sample and alloy in it, and then close the cornucopia tightly around the sample. The lead foil must be compactly folded around the sample in order that it may be easily handled with the cupel tongs, and of such shape that it will be contained in the cupel without overhanging the edges.

Bring the muffle to a bright red heat, and place the cupels to be used in the muffle at least ten minutes before using them so that they will be at the same temperature as the muffle. With the cupel tongs place the folded lead foil containing the drillings and silver alloy in the cupel, in the muffle; use great care while conveying it with the tongs to the cupel so that it does not fall onto the bottom of the muffle, as such a mishap would not only necessitate weighing and alloying another sample, but should the lead melt before it could be scraped out, it would make a weak

place in the floor of the muffle which would soon give way and have to be replaced. Close the muffle with the plug and leave closed until the sample and lead are fused together and have become slightly molten. This may take five or six minutes, when the plug must be removed so that fresh air may be admitted for oxidizing purposes. The fumes of the volatilizing lead carry all the base metals contained in the bullion sample, and will be seen rising like smoke from the cupel.

FIG. 33—Bullion bead pliers.

The cupellation is finished when the gold and silver bead has "set," which is shown by the fact that no more fumes come from the cupel, and a solid hemispherical bead remains. The distinction between a "set" and "frozen" bead is explained under the head of cupellation (Chapter II).

"E" Rolling Coronets and Annealing.—Remove the cupel containing the gold and silver bead from the muffle with the proper tongs. The bead may then be taken from the cupel with a pair of bullion bead pliers (Fig. 33) and must be thoroughly cleaned of any adhering bone ash with a stiff brush (see Fig. 22).

Roll (or hammer if the operator has no coronet roll, Fig. 34) into a thin strip or disc having less than half the thickness of a ten cent piece. This hammering must be done on a smooth faced steel block. After every few blows pick up the bead with a pair of forceps

FIG. 34—Coronet roll.

and hold it in the flame of an alcohol lamp or Bunsen burner until the bullion is red hot (Fig. 35). This is called annealing, and expands the metal by opening the pores that have been closed by the hammering or rolling. This is necessary as otherwise the bullion would crack, and small pieces would chip off and be

lost. When the bullion has been repeatedly rolled or hammered and annealed until sufficiently thin, it is then, after a final annealing, ready to "part."

FIG. 35—Annealing bullion bead.

"F" Parting.—The rolled or hammered strip is then bent or coiled into a coronet so that the acid will have a chance to act on the maximum surface. The

final annealing leaves the pores of the metal open to the action of the acid.

Place the coronet in an Erlenmeyer flask (Fig. 36) of 6 or 8 ounces capacity, and cover with ½ ounce of chemically pure nitric acid and distilled water, about 5 parts water to 1 part acid. Put the flask on the sand bath (Fig. 37) and apply very gentle heat. The acid will soon begin to act, as will be shown by the small bubbles of hydrogen and by the blackening of the coronet. Should the action of the acid be too violent and the bullion immediately become black, add a little more distilled water, as when the operation of partition is performed too rapidly, there is danger of breaking up the coronet, which will leave the gold in fine particles or pieces which cannot be washed and transferred without loss. It is also desirable to have the gold coronet left in one piece as then there is less danger of loss in transferring the gold to the scale pan. Should the acid fail to act upon the coronet after a few minutes, add chemically pure nitric acid, a few drops at a time until action commences. Then when the action subsides add more nitric acid a few drops at a time. When this latter addition of acid causes no giving off of fine bubbles and the coronet is

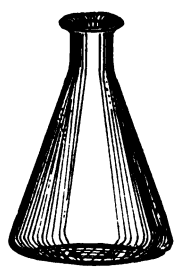

FIG. 36—Erlenmeyer flask.

black, it is safe to assume that the silver has mostly been dissolved out of the coronet, leaving a sponge of gold. Now pour off the diluted acid into a receptacle for containing silver, cover the sponge-like coronet with strong chemically pure nitric acid, and boil until

Fig. 37—Parting bullion coronet in flasks on sand bath.

no more red fumes are given off. The partition is then complete. Pour the acid into the receptacle and wash the black sponge-like coronet three or four times with hot distilled water. This is to remove any trace of the silver nitrate that may be left in the pores of the coronet.

Transfer the coronet from the Erlenmeyer flasks to an annealing cup (Fig. 38) which is best done by holding the flask in one hand and the annealing cup (Fig. 39) in the other, submerging both hands in water, allowing both cup and flask to fill, and while both are under water inverting the flask into the annealing cup, when the coronet by gravity will slowly drop down into the cup. This prevents any dust from blowing away, and is the only safe way of transferring from the flask to the annealing cup should the gold be in a broken-up state. Remove the cup carefully from its submerged position, drain off all the water and carefully dry on the sand bath, applying the heat very gently until all the moisture is evaporated. When thoroughly dry brighten or anneal the gold coronet either by placing the annealing cup in the muffle and heating red hot, or by holding the cup in the flame of a Bunsen burner (Fig. 40) or alcohol lamp (Fig. 41) until the cup and gold are red hot. This operation restores the gold from the brown or black color to its natural golden hue. Cool to the temperature of the atmosphere, and when cool carefully weigh and note

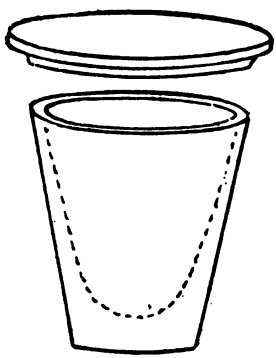

FIG. 38—Annealing cup.

the weight on the card which contained the original weight of the sample.

"G" Calculating Results.—The percentage of fine gold contained in the sample is found by dividing the net weight of the assay (the weight of pure gold) by

FIG. 39—Transferring coronet from flask to annealing cup under water.

the gross weight, *i.e.*, the weight of the original sample of the drillings. Assuming the original weight to have been 300 milligrams, and the weight of the coronet after partition to be 210 milligrams, the gold fineness would be 210 ÷ 300 = 700 gold fine.

"H" To Determine the Silver Fineness or Percentage of Silver in the Gold Bullion.—Weigh accurately from 300 to 500 milligrams of the drillings. Note the weight on the tag or card which bears the number of the assay. Do not alloy, but wrap the weighed sample in the lead foil and cupel exactly in the manner just described.

FIG. 40—Bunsen gas burner.

When the cupellation is properly finished all the base metals have been carried off by the volatilized lead, and the "set" bullion bead contains the gold and silver alone. Carefully clean the bullion bead and weigh when cold, noting the result. The weight of the gold and silver divided by the weight of the sample before cupellation will give the percentage of gold and silver together contained in the sample. Determine the gold fineness of this sample in the manner just described in the operation previous to this one. Subtract the gold fineness from the gold and silver fineness, and the remainder will represent the silver fineness, or the percentage of silver contained in the sample.

FIG. 41—Alcohol lamp.

In the operation previous to this one, the gold value was found to be 700. If after wrapping the sample of 300 milligrams in lead without adding silver and cupelling, the weight of the button is 270 milligrams, we find by dividing 270 milligrams by 300 milligrams, the percentage of gold and silver together contained in the sample is 900. By subtracting the gold fineness, which we found to be 700, from the gold and silver fineness 900, we have 200, which is the silver fineness of the sample.

Should the bullion contain much base metal such as copper, for example, the button might freeze or solidify in the cupel before the copper had all been carried off by the volatilizing lead. This is remedied by rolling up a piece of lead foil (5 or 10 grams) and dropping it with the cupel tongs into the cupel containing the frozen button. When this is done close the muffle with the plug, and leave it until the frozen button and lead have fused together and have become brightly molten. Then remove the plug and continue the cupellation until the bead "sets." The difference between a frozen button and a set bead is readily discerned. The frozen button has a peculiar coated appearance, while the bead which has perfectly set appears lustrous and clean when all the base metals have been carried off with the lead.

CHAPTER V.

FIRE ASSAY OF LEAD.

"*A*" Usual Charge.—"*B*" Melting.—"*C*" Recovering Lead Button.—"*D*" Estimating Percentage of Lead.

"*A*" *Usual Charge.*—Take 10 grams of ore, pulped and sampled as heretofore described, add 10 grams of potassium cyanide, 20 grams of bicarbonate of soda; mix thoroughly, and after placing it in the crucible, cover top of charge with 2 or 3 grams of potassium cyanide. With galena ores, put several (3 or 4) bright wire nails into the crucible with the charge. By using large nails they may be readily removed with the crucible tongs before the crucible is set aside to cool.

"*B*" *Melting.*—This assay is well made in the crucible chamber of a gasoline furnace and the melt should be ready to pour after twenty minutes. Carefully remove the nails before taking the crucible from the furnace. The reduction is perfect when the charge in the crucible has ceased boiling and has subsided.

"*C*" *Recovering Lead Buttons.*—When the crucible and contents are cool, break the crucible and recover the lead button. The lead should all be in the bottom of the crucible in one button. If the slag contains globules of lead the charge was not well melted, and

was removed from the furnace too soon. Hammer the button free from all slag on a flat anvil and weigh.

"D" Estimating Percentage of Lead.—The weight of the lead button, divided by the weight of the ore taken, will give the percentage of lead in the ore. If 10 grams of ore were taken, and the button weighs 2 grams, then, $2 \div 10 = .20$, the percentage of lead. The lead button should be very ductile. If hard and brittle it may contain antimony and other metals. (See antimony assay.)

CHAPTER VI.

FIRE ASSAY OF ANTIMONY.

"*A*" Usual Charge.—"*B*" Melting.—"*C*" Recovering the Button.—"*D*" Estimating Results.

"*A*" *Usual Charge.*—Mix 10 grams of the pulped ore with 40 grams of pulverized potassium cyanide.

"*B*" *Melting.*—Put the charge into a 20 gram crucible or one of equivalent capacity, and cover the top of the charge with about 10 grams of dry table salt. The salt cover prevents the charge from boiling over the top of the crucible. The reduction should be made in twenty minutes in the melting chamber of a gasoline furnace. When the reduction is complete, which may be known by the quiescent state and the fluidity of the charge, remove the crucible from the furnace and cover with a crucible cover.

"*C*" *Recovering the Button.*—When it is cold break the crucible to recover the button. Be careful in breaking the crucible as the button will be very brittle.

To separate foreign metals, break up the button into fine particles and add chemically pure nitric acid, which converts the antimony to antimonic acid which is insoluble. Filter, wash, dry and ignite in a porcelain crucible.

"D" Estimating Results.—Antimonic acid is 79 per cent metallic antimony; therefore multiply the weight found by .79, which will give the amount of metallic antimony. Where a small filter is used the weight of the ash may be ignored. The ignition consists in drying the filter containing the antimonic acid and in heating it red hot. See that the filter is reduced to a white ash and is not simply carbonized. This may be done in a porcelain crucible (see Fig. 26), in the muffle or in the flame of a Bunsen burner.

CHAPTER VII.

WEIGHING.

"*A*" Balances.—"*B*" Weights.—"*C*" Weighing.

"*A*" *Balances.*—Buy a good button balance, for should the final weighing of the gold or silver recovered from an assay charge be inaccurate, all the previous work will have been wasted.

A good button balance can be purchased for $100.00 (Fig. 42); higher grades that are more sensitive and delicate of construction will cost proportionally more. It is desirable to have all the bearings of the button balance of agate or sapphire. By the bearings are meant the knife edges and all the parts called planes that make a contact with the knife edges.

Pulp scales sufficiently delicate may be bought at prices ranging from $5.00 to $50.00. It is advisable, however, for this purpose to have a balance sensitive to at least 1 milligram (Fig. 43).

Analytical balances (Fig. 44) range in price from $50.00 upward, and are intended to be accurately sensitive to a weight of from 0.1 to 0.05 milligram.

Any first-class pulp balance will be sufficiently accurate for all the purposes of the ordinary assayer, such as weighing the pulp used in making volumetric

Fig. 42—Button Balance.

FIG. 43—Pulp Balance.

FIG. 44—Analytical Balance.

assays of copper, etc., or any ordinary gravimetric determinations.

Keep the button balance in a clean dry place, and do not expose it to acid fumes. Set the button balance upon a support that does not vibrate, and always level the balance before using.

FIG. 45—Weight forceps, ivory tip.

Do not handle the small weights except with the forceps (Fig. 45) supplied for that purpose. Remove and replace the scale pans with the forceps, and brush off any dust that may gather in the pans with a camel's-hair brush (Fig. 46).

FIG. 46—Camel's-hair brush for scale pans.

"B" Weights.—The French or metric decimal system of weights and measurements is eminently the best, and is in general use for the laboratory (see tables, page 128).

Assay Ton.—The assay ton consisting of 29.166 grams is the unit of pulp measurement for fire assay (see table, page 128). The milligram, which we may

term the unit weight of the assay balance, bears the same relation to the ounce troy that the assay ton (29.166) bears to the ton avoirdupois.

The assay ton weight was created so that when 1 assay ton of ore was taken, each milligram of pure gold as shown by the button balance would represent 1 ounce troy in gold to the ton avoirdupois of the sample assayed. This system simplifies the figuring of valuations, as each milligram of gold recovered from an assay ton of pulp represents 1 ounce troy per ton avoirdupois, or a value at present of $20.67 per ton.

"C" Weighing.—The assay is weighed by putting the bead into one pan of the button balance and counterpoising with the requisite number of milligram weights placed in the other pan. The bead should never be handled except with the forceps. It is placed upon the left pan of the balance, and the weights are then put in the right pan also with the forceps. The balance must always be arrested before putting anything in or removing anything from the pans; by arresting is meant that the pans must be rested upon their supports. Adjust the balance every time before using, as a small deviation will materially affect the result. Estimate the probable weight the bead will have and put the highest estimated weight in first, then the next lower and so on until the exact scale weight is obtained. This is the only way to preserve

the balance from bumping, and time will be saved by being systematic. The weighing operation is then completed by sliding the rider along the beam until the pan is exactly counterpoised.

The weight is written decimally in milligrams and fractions thereof; the number of milligrams being shown in the weight pan, and the fractions of a milligram being shown by the rider.

If the beam has fifty graduations on each side of the central bearing of the beam, each graduation or division (provided a 1 milligram rider is used) represents the 1/50 part of a milligram or decimally 0.02 of a milligram.

CHAPTER VIII.

FLUXES.

"*A*" General Flux.—"*B*" Specific Fluxes or Flux for Specific Cases.—"*C*" The Fluxes Generally Used and their Action.—"*D*" Scorification Fluxes.

"*A*" *General Flux.*—In a laboratory where much work is done in a day, and the class of ore is uniform, what is called a "general flux" may be made. This flux is adapted to ores that may be classified as average, but is so compounded as to allow the addition of extra litharge and reducing agent. A general flux of this nature may be made of the following ingredients:

3½ pounds of litharge, free from silver (lead oxide)
3 pounds of sodium bicarbonate
2 pounds of borax glass
1 pound of silica or powdered glass
3 ozs. of flour.

Mix these thoroughly through a 40 mesh sieve. The object of preparing this general flux is to save the necessity of weighing out the flux for each individual assay sample. This flux does not contain quite enough litharge for an average ore, and for average ores about twelve grams of litharge should be added to the charge. The reason for omitting this amount of litharge in the flux is that in the case of ores containing lead too large a lead button would result. In

fluxing an average gold and silver ore, weigh 1 assay ton of ore and add 12 grams of litharge and 2½ assay tons of the general flux. In the fluxing of an ore containing lead omit the addition of the litharge. These brief instructions as to using general flux are presented in order that the student may have a starting point, and his subsequent experience will enable him to make changes to fit varying conditions.

The weighing of fluxes for each and every assay may be avoided by using measures of known capacity. These measures will save the time spent in weighing.

"B" Specific Fluxes or Flux for Specific Cases.

FOR LIME ORES.

Ore	1 A.T.
Litharge	2 A.T.
Silica or Glass	3 A.T.
Argol	1.5 grams
Salt Cover	10 grams

FLUX FOR LIME ORES WITH HEMATITE.

Ore	1 A.T.
Sodium Bicarbonate	1 A.T.
Silica or Glass	2 A.T.
Argol	1.5 grams
Borax Glass	10 grams
Salt Cover	10 grams

FLUX FOR IRON PYRITES.

Ore	½ A.T.
Litharge	¾ A.T.
Sodium Bicarbonate	½ A.T.
Silica or Glass	½ A.T.
Argol	0.85 gram
Borax Glass	0.5 gram
Salt Cover	10 grams

"C" The Fluxes Generally Used and Their Action.

Sodium Bicarbonate—Basic Oxidizer; Desulphurizer.

Potassium Cyanide—Reducer and Desulphurizer for lead assay.

Argol—Basic Flux; Reducer.

Charcoal—Reducer and Deoxidizer.

Starch, Flour, Sugar—Reducer.

Metallic Iron—Desulphurizer.

Lead and Lead Oxide (Litharge)—Basic Flux; Oxidizer.

Nitre—Basic Flux and Oxidizer.

Powdered lime Fluor spar Magnesia Aluminia Kaolin	Basic fluxes.
Borax Borax glass Boracic acid Silica Lime glass	Acid fluxes.

"D" Scorification Fluxes.

To scorify the following, take:

GALENA.—1/10, A.T. Test, Lead 16 grams, Borax Glass about 0.5 gram.

LEAD CARBONATE.—1/10, A.T. Test, Lead 16 grams, Borax Glass about 0.5 gram.

LEAD MATTE.—1/10, A.T. Test, Lead 30 grams, Borax Glass about 0.75 gram.

IRON PYRITES.—1/10, A.T. Test, Lead 35 and 10 grams (grams litharge), Borax Glass about 0.5 gram.

GRAY COPPER.—1/10, A.T. Test, Lead 50 grams, Borax Glass about 0.5 gram.

COPPER MATTE.—1/10, A.T. Test, Lead 40 grams, Borax Glass about 0.5 gram.

ARSENICAL PYRITES.—1/10, A.T. Test, Lead 50 grams, Borax Glass about 1.0 gram.

BLENDES.—1/10, A.T. Test, Lead 40 grams, Borax Glass about 0.5 gram.

SILICIOUS ORE.—1/10, A.T. Test, Lead 30 grams, Borax Glass, none.

TELLURIDES.—1/10, A.T. Test, Lead 60 grams, Borax Glass about 0.5 gram.

By practice the operator can determine whether more lead than given above gives higher results in silver. It is impossible to formulate an invariable system, as different conditions give different results.

The ore charges selected for scorifications vary from 1/10 (.1) to 1/5 (.02) assay ton. The size of scorifiers selected must be governed by the size of the ore charge.

CHAPTER IX.

TOUCH STONE AND TEST NEEDLES.

"*A*" Description of Touch Stone and Test Needles.—"*B*" Method of Using.—"*C*" Accuracy Possible.

"*A*" *Description of Touch Stone and Test Needles.*—The touch or test stone is practically a small black whetstone. Test needles (Fig. 47) are a number of slim pointed brass fingers, one end having gold points of different fineness expressed in karats (the karat is the jeweler's standard of measure for gold, and 24 karats is pure gold). The test needles range from a 2 karat point up to a 20 karat point, advancing 2 karats at a time. Six karat gold would be 6/24 pure, 8 karat gold would be 8/24 pure gold, etc.

"*B*" *Method of Using.*—What is termed a streak is made on the stone by rubbing the gold (Fig. 48) to be treated across it, which leaves a narrow streak of the metal ground off upon the surface of the stone. This infinitely thin streak is made up of the gold and whatever alloy is with the gold. Then draw across both streaks a wet glass stopper from a bottle containing chemically pure nitric acid.

The test, which is to find approximately the karat of the gold, is based upon the fact that the nitric acid

used in testing dissolves the alloy in the streak and leaves the gold untouched. The test is comparative and colorimetric. Comparative, because compared with a second streak of known fineness made from such of the test needles as is assumed to be nearest the fineness of the gold being tested. Colorimetric, because after applying chemically pure nitric acid to both

FIG. 47—Test needles.

streaks simultaneously, a comparison may be made between the color of the two streaks. The one having the most color or showing the greater amount of gold after the alloy is dissolved out of the streak by the acid, is the finer.

If the gold tested shows a stronger streak than the needle streak, it is evident the gold was finer than the needle, and a still finer needle may be tried against it.

When no difference between the streak of the gold tested and that of the needle is discernible, it is safe to assume that the gold is of approximately the same karat as the needle whose fineness is a known quan-

FIG. 48—Testing gold fineness with test needles and touch stones.

tity. In making streaks for comparison, endeavor to grind on to the stone an equal amount from the needle and the object tested. Should any doubt exist as to which streak is the finer after having applied the nitric acid, dip a wooden toothpick or splinter into some

hydrochloric acid and rub the moistened end of the splinter across the two streaks where the nitric acid was applied. The poorer streak will disappear first, as aqua regia was formed by the mixing of the acid on the splinter and the nitric acid on the streaks, and naturally the streak having the least gold left in it will disappear first as aqua regia readily dissolves gold.

"C" Accuracy Possible.—Practice and care in manipulation will soon enable one to estimate within .050 the fineness of gold tested in this manner. A touch stone and alloyed needles are very convenient adjuncts to a laboratory, as by their use preliminary to making a bullion assay, an approximate idea of the fineness of bullion to be assayed may be had, which will allow the assayer to properly alloy his bullion assays for partition.

CHAPTER X.

VOLUMETRIC DETERMINATION OF COPPER.

WITH SOLUTION OF POTASSIUM CYANIDE.

"*A*" Preparation of Sample.—"*B*" Usual Charge.—"*C*" Method of Treatment.—"*D*" Determining the Amount of Copper.—"*E*" To Make a Standard Solution.

The general method of assaying copper values is by what is termed the "wet" process, that is volumetric determination by titrating with standard solution of potassium cyanide. This method is very accurate when carefully done, but care must be taken to keep the standard solution at a given strength.

"*A*" *Preparation of Sample.*—The original sample of ore must be thoroughly mixed, quartered and pulped as described in Chapter I for gold and silver assay, except that pulp for solution or "wet" assays should be more finely pulverized than samples prepared for fire assay. Pulps for this operation should pass a sieve of 100 mesh.

"*B*" *Usual Charge.*—Carefully weigh 0.5 gram (in case the ore be rich in copper), and place in a 250 c.c. beaker (Fig. 49).

"*C*" *Method of Treatment.*—Add 1 fluidounce of mixed nitric and hydrochloric acid, having 2 parts nitric and 1 part hydrochloric. Place the beaker on

the sand bath (Fig. 50), and apply gentle heat. As the acid evaporates from the beaker, maintain the original volume by the addition of water from time to time, using the wash bottle (Fig. 51) during the operation, and continue until the fumes cease. Before removing the beaker from the sand bath add drop by drop a very few drops of chemically pure sulphuric acid. This drives off any remaining nitrous oxide (red fumes) and helps to clean the solution. Agitate the solution from time to time by stirring with a glass rod. The copper contained in the sample will now be in solution, and the silica or insoluble matter will look clear and white. This digestion will ordinarily take from ten to fifteen minutes. When the silica or gangue matter shows clear and white, bring up the volume in the beaker to about four ounces by adding warm water. Empty the contents of the beaker upon a small filter paper about seven inches in diameter previously folded and placed in a glass funnel (Fig. 52).

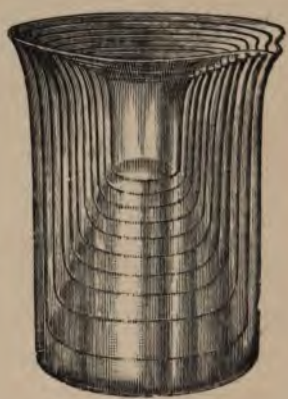

FIG. 49—Glass beaker.

FIG. 50—Sand bath, iron.

Rinse out the beaker with hot water, pouring it through the filter. Then carefully wash filter and gangue matter with hot water, using the wash bottle. This is to make sure that all copper solution may be washed out of the gangue and out of the filter paper into the receiving beaker beneath the funnel.

Fig. 51.—Wash bottle.

Add to the filtrate some stronger ammonia water until the filtrate becomes strongly alkaline, which will be shown by a deep blue color. Place filter containing the now alkaline filtrate on the sand bath, and bring it slowly to the boiling point. This operation precipitates all iron and alumina out of the solution. Prepare clean filter paper in the funnel and filter out precipitated iron and alumina. Wash the filter thoroughly with hot water as before so as to remove all traces of copper from the precipitate on the filter. The filtrate when cool and brought up to a volume of 10 or 12 ounces, is now ready for titration, which is performed in exactly the same manner as described in the determining of the

Fig. 52.—Glass funnel.

strength of the solution of potassium cyanide (see page 80). Perform this operation carefully, and note the reading of the burette (Fig. 53).

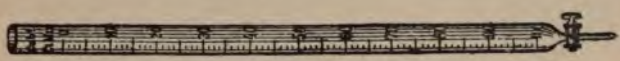

FIG. 53.—Burette.

"D" Determining the Amount of Copper.—Assuming that it took 35 c.c. of potassium cyanide solution to decolorize the alkaline solution containing the 0.5 gram of pure copper, and that 10 c.c. were required to decolorize the copper solution from 0.5 gram of copper ore, the amount of copper in the ore would be determined as follows: the number of cubic centimeters of potassium cyanide solution assumed as a standard, viz., 35 c.c., bears the same relation to 100 per cent or the whole as the number of cubic centimeters used to decolorize the copper contained in the solution from 0.5 gram of copper ore bears to the total per cent of copper in that amount. The equation would read as follows: 35 c.c. : 100 per cent : 10 c.c. : x per cent, x per cent equalling 28.57, the percentage of copper in the 0.5 gram of ore. To simplify, this may be determined as follows: divide the number of cubic centimeters required to decolorize the copper solution from 0.5 gram of ore by the number of cubic centimeters that indicates the strength

of the potassium cyanide, and the result would be the percentage of copper ($10 \div 35 = 28.57$).

When the copper ore is not rich take from 2 to 4 grams, and divide the resulting percentage shown after titrating to reduce the result to the basis of 0.5 gram of ore, viz.: if 2 grams of ore were titrated, the 2 grams would be 4 times the 0.5 gram which represents the 100 per cent in making the standard, consequently the resulting percentage must be divided by 4 to give the true value.

"E" To Make a Standard Solution.—Dissolve ½ pound of chemically pure potassium cyanide in 1 gallon of distilled water. This solution should stand at least twenty-four hours before using, and should be kept in a dark bottle wrapped in paper, as exposure to the light weakens the strength. The strength of the solution is determined in the following manner: dissolve 0.5 gram of chemically pure copper foil accurately weighed in 1 ounce dilute chemically pure nitric acid composed of 5 parts water and one part acid. Dissolve the copper foil in this solution at a gentle heat on the sand bath. When the foil is in solution bring up the volume with water to a bulk of 10 ounces and add chemically pure stronger ammonia water until the solution is alkaline, which will be known by the intense blue color and the alkaline fumes of the ammonia. After cooling this solution it is now

ready to titrate, which operation will show the strength of the aqueous solution of the potassium cyanide.

Fill a 50 c.c. burette (see Fig. 53) with the potassium cyanide solution. Draw off a little of the solution from the burette through its stopcock so that the stopcock may be filled with the solution before the titration is commenced. Note where the solution stands in the burette and make a memorandum. It is better to commence with the burette full to the 50 mark or on some whole number. Do not read the burette by the capillary mark of the solution around the edge of the burette, but from the meniscus or lowest point. Place the beaker under the burette, run in the potassium cyanide solution slowly from the burette, all the time stirring the copper solution with a glass rod. Continue this until all the color from the copper solution disappears, and the liquid has become perfectly white. The last part of the operation must be done very slowly, the potassium cyanide solution added drop by drop, and after each drop the solution must be carefully stirred with the glass rod. The addition of too much potassium cyanide solution will turn the solution in the beaker yellow. Care must be taken to stop as soon as the last trace of blue color has disappeared.

This operation should be performed in a good light and the beaker placed on a piece of white paper or a

white base. When this is completed read the burette, and note the number of cubic centimeters of this solution used to decolorize the solution containing 0.5 gram of chemically pure copper. This now becomes an arbitrary standard of the strength of the cyanide of potassium solution, and should be noted on the label of the bottle. This solution should be tested from time to time, once a week if used frequently, as its strength is not permanent.

CHAPTER XI.

MODIFICATION OF KERL'S SWEDISH COPPER ASSAY.

"*A*" Usual Charge.—"*B*" Method of Treatment.—"*C*" Determining Amount of Copper.

"*A*" *Usual Charge.*—Put 5 grams of the finely pulped ore in a beaker or preferably in a porcelain casserole (Fig. 54).

"*B*" *Method of Treatment.*—Add about 20 c.c. of hydrochloric acid and 10 c.c. of nitric acid. Place the vessel on a sand bath and apply gentle heat.

Stir the material being treated from time to time with a glass rod. It is safe to assume that the decomposition is perfect when the silica or residue is clear. When the decomposition of the ore is complete add very gradually a few drops of sulphuric acid to dispel the nitric acid, which must be done before the copper can be perfectly precipitated with iron. If, upon adding a few more drops of sulphuric acid, no more red fumes of nitrous oxide appear, the nitric acid has been driven off. Now evaporate nearly to dryness and add hot water, being careful not to break the

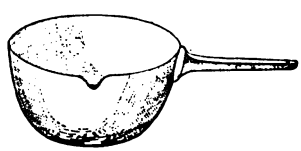

FIG. 54—Porcelain casserole.

container by adding the water too suddenly. Filter and wash the residue on the filter paper several times with very hot water, using the wash bottle. This residue is thoroughly washed when the washings will not coat a bright iron wire with copper. The volume of the filtrate should now be about 6 ounces. (Use 500 c.c. beaker.)

Place a dozen pieces of bright iron wire in the beaker containing the filtrate. (Tenpenny wire nails will answer for this purpose.) Heat the filtrate containing the wires nearly to the boiling point. When the solution becomes clear and no longer deposits a brownish coat upon a clean iron wire held in the solution, the copper is all precipitated. When the precipitation is complete fill the beaker with hot water and allow it to stand ten minutes; then carefully pour off the solution from the wires or nails and precipitated copper. Fill the beaker again with hot water and carefully transfer the wires and water and all of the precipitated copper which is not adhering to the wires to a porcelain evaporating dish (Fig. 55) large enough to receive the contents of the beaker. Rub the wires free from the adhering copper with the fingers, then rinse and remove the wires, being particular

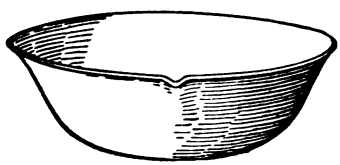

FIG. 55—Porcelain evaporating dish.

that none of the copper is lost. Allow the contents of the dish to settle a few minutes, then decant or pour off the fluid. Again wash the precipitated copper with hot water; settle and pour off. Dry the copper at a gentle heat and when thoroughly dry weigh as metallic copper. (Any danger from oxidizing the copper while drying may be obviated by adding a little alcohol before drying.)

"C" Determining the Amount of Copper.—Divide the weight of the metallic copper recovered by the weight of ore treated, and the result will be the percentage of copper contained in the ore. If 5 grams of ore were treated and 1 gram of copper resulted, the percentage of copper in the ore would be $1 \div 5 \times 100 = 20$, the percentage of copper. This assay is accurate except in cases where the ore contains much tin or antimony. These metals, however, are rarely combined in any quantity with copper ore.

CHAPTER XII.

ELECTROLYTIC ASSAYING WITH THE GUESS-HAULTAIN ELECTROLYTIC OUTFIT.

The increasing demand for greater speed and more accuracy in making daily assays of ores and products from mills treating material containing but very small quantities of lead and copper, has caused the older electrolytic methods to be supplanted by new ones, devised to meet the needs of modern work.

The usual form of electrode in use at the present time consists of platinum cylinders and spirals, or cones and spirals, costing in the vicinity of from $15 to $20 each, making the installation of many units very costly. In order to overcome this expense, Mr. George A. Guess, together with Mr. H. E. T. Haultain, have designed and patented a cheaper form of electrode.

The form of cathode adopted as most satisfactory is shaped into a blade having an immersion area of about 50 sq. cm. The blade is sand blasted and corrugated lengthwise in order to impart the necessary rigidity. Strips of platinum foil corrugated and sand blasted form the anodes. Three electrodes are used in each cell. These electrodes are connected with slotted aluminum terminals, in which they are held by contact pressure. At the back, the anodes are con-

Fig. 55*a*—Guess-Haultain Electrolytic Outfit.

nected with one pole of the current and the cathodes with the other pole.

Cabinets are made up of any number of units. In battery sets they are connected up in parallel, and for power current they are connected in series. Suitable rheostats for controlling the current and also ammeters for reading are furnished with each outfit. The cost of the outfit complete, for any number of units, including cabinet, ammeter, rheostat, connectors, beakers and electrodes, will be found to be less than the cost of the old type of electrodes. In addition, the time necessary to make an estimation is a feature that most readily appeals to all operators, as determinations of copper ores can be made in three hours and lead ores in two hours, whereas in the old form from ten to twelve hours are necessary.

Power current is always recommended where available, either alternating or direct. With alternating current a rectifier is used to change it to direct.

Where power current is not procurable an outfit for use with battery current has been perfected.

These cabinets have been installed in the laboratories of many of the large copper mines, smelters, educational institutions, etc.

Procedure for Copper Ores.—Weigh 0.5 gram ore (1 gram for low-grade ores) into a 100 c.c. tall beaker; add 5 c.c. nitric acid and 1 to 1.50 c.c. sulphuric acid;

boil gently to fumes; bake dry to remove any sulphur cakes; cool; add 5 c.c. nitric acid and 20 c.c. water, and boil gently five minutes. Add 1 c.c. nitro compound, fill with cool water, allow to settle, and electrolyze with 1.5 amp. for three hours.

For simple ores and concentrator products, weigh 0.5 to 2 grams, as necessary, into the 100 c.c. beaker; add 7 to 8 c.c. nitric acid; boil gently with the beaker covered until free from nitrous fumes, leaving 5 to 6 c.c. free acid. Add 1 c.c. nitro compound, fill with cool water, allow to settle and electrolyze as above.

The nitro compound is prepared by digesting 25 grams No. 4 hard oil of the Standard Oil Company in 250 c.c. nitric acid on a warm plate for 12 hours. Dilute with cold water to 500 c.c., mix thoroughly and filter. The action of the nitro compound is to retard the sudden deposition of copper when the current is first passed through the solution, and to allow a slow, constant deposition, giving a hard, clean deposit. It prevents the deposition of the small amounts of antimony contained in our ores. If the compound is too concentrated, a scum may form about the top of the electrode, when the copper depositing about it will leave a dark brown streak which cannot be removed and gives too high a result. On slags and low-grade tailings, the nitro compound is of little advantage.

The Electrolysis.—On standing five minutes all 0.5 gram charges are sufficiently settled to begin electrolysis. Two-gram charges take longer and fine slimes may not settle entirely. The latter may be filtered or the copper redeposited from the first cathode on a clean cathode for absolute results, but for ordinary work the first deposit is sufficiently accurate, the increase being but a few hundredths of one per cent.

Before starting electrolysis the anodes must be set firmly in the slots and at equal distances from the cathodes (otherwise, the deposition will be uneven and violent evolution of gas at the cathode will occur, giving a dark deposit). On starting electrolysis, evolution of gas at the cathode is common and occurs less frequently during and at the end of the operation. This may be stopped by an instantaneous short circuit of the assay.

It has been proved that in the three hours with a 5 to 6 per cent of acid solution, the deposition of 0.025 gram copper is absolutely certain and that 0.050 gram can be deposited, leaving but a faint trace of copper in solution. This gives the limit of a 10 per cent Cu on 0.5 gram ore. Beyond this point it is advisable to allow the assay to remain one-half to one hour longer according to the copper contents, adding 1 c.c. nitric acid and 0.5 c.c. nitro compound if it is found that the deposit turns dark or the solution

becomes too greatly heated. The discrepancy from the theoretical is due to the fact that the theoretical deposition is from a saturated solution and such conditions never occur in practice.

Care of Electrodes.—At the end of electrolysis, the cathodes are removed either by lifting out of the beaker or by lowering the beaker, washed thoroughly, dipped in alcohol, dried and placed on velvet trays. The deposits are hard and firm, eliminating any danger of removal of copper by handling. The electrodes are cleaned by dipping in warm nitric acid, washing thoroughly and allowing to stand, handles covered, in boiling dilute caustic soda. With this treatment, the weight changes 0.0001 to 0.0002 gram in 10 days.

This method under the conditions described is entirely satisfactory and removes as much as possible the personal equation so vital to all methods. One man can handle 200 assays in a day and have sufficient time to do other work about the laboratory. Experiments have also been made on smelter flue dust and copper-dummies containing large amounts of arsenic and antimony. In these cases the results were always satisfactory.

Procedure for Lead Ores.—A weight of 855 mg. is advised in order to avoid the necessity of calculating each result, the weights of peroxide found being called lead.

The ore, weighed into a tall battery-beaker of 100 c.c. capacity, is digested with 10 c.c. of nitric acid. The lead sulphate formed is readily dissolved after boiling, by the addition to the beaker of 10 to 20 c.c. of a saturated solution of ammonium nitrate containing 20 per cent of free ammonia. After solution, the beaker is nearly filled with water, and from 10 to 20 c.c. of nitric acid added. The solution is now ready for electrolysis. A wide range of current strength is permissible, but from 1.5 to 2 amperes is most satisfactory; this amount keeps the solution sufficiently hot during the electrolysis. At the end of two hours, the lead is completely deposited in the form of peroxide on the anode. The anode is then removed, washed in water and in alcohol, ignited and weighed. The theoretical factor is 0.866; but in practice 0.855 is found to be more accurate; probably due, as Hollars says, to an excess of oxygen in the peroxide.

The accuracy of this method ranks with that of carefully made electrolytic coppers, and its great advantage is the small amount of the chemist's time required. In the presence of manganese or antimony, it is necessary to have a large excess of free nitric acid in the electrolyte, under which condition neither element interferes. Bismuth, even in the presence of very large amounts of free nitric acid, is partly precipitated as bismuth oxide with the lead. Its presence can be

recognized by a light blue color given to the peroxide coat. Arsenic and tellurium have to be removed before electrolysis, for if present in large amounts they effectually prevent any deposition of lead. Unless the anode is sand blasted, only a comparatively small amount of peroxide will adhere, but properly sand blasted, adherent deposits of 250 mg., and even up to 600 mg. of peroxide may be obtained in daily work.

CHAPTER XIII.

WET ASSAY OF LEAD.

"*A*" Amount and Preparation of Sample.—"*B*" Method of Treatment.—"*C*" Determining the Percentage of Lead.

"*A*" *Amount and Preparation of Sample.*—Place 2 grams of ore pulped to 100 mesh in a six-ounce beaker and add a small quantity of diluted nitric acid.

"*B*" *Method of Treatment.*—Boil over a Bunsen burner until red fumes cease, then add a few drops of sulphuric acid and evaporate gradually to dryness. (If the ore contains considerable limestone, use dilute sulphuric acid, and do not evaporate to complete dryness.) When the evaporation has taken place, add more water and heat slightly, stirring frequently. Wash in funnel with filter paper until filtrate ceases to give acid reaction (*i.e.*, until the washings do not turn blue litmus paper red). Remove the filter and wash off residue into a porcelain dish with a neutral solution of carbonate of soda (neutral means neither acid nor alkaline). Digest for one hour. This converts lead sulphates to carbonates. Filter and dissolve the residue in acetic acid, and add gradually just enough sulphuric acid to precipitate the lead as lead sulphate; sufficient sulphuric acid has been added when further addition ceases to cloud the solution.

When the first precipitation of lead as lead sulphate has been made, settle and pour off the fluid very carefully from the precipitate. Carefully wash the lead sulphate into a porcelain capsule or a small porcelain evaporating dish; settle and pour off the water and carefully dry the lead sulphate. When dry, heat in the capsule or dish to redness. Then allow to cool and take the weight.

"C" Determining the Percentage of Lead.—Multiply the weight of the lead sulphate by 0.6832, which will give the weight of the metallic lead. The weight of the metallic lead divided by the weight of the amount of ore treated will be the percentage of lead contained in the ore.

If 2 grams of ore were treated and the amount of metallic lead was found to be 0.5 gram, then $.5 \div 2 \times 100 = 25$, the percentage of lead.

CHAPTER XIV.

VOLUMETRIC DETERMINATION OF LEAD BY THE MOLYBDATE METHOD.

"*A*" Method of Determination.—"*B*" Standardization of the Ammonium Molybdate Solution.—"*C*" Preparation of the Tannin Indicator.

This method, on account of its rapidity and ease of manipulation, in many instances, is supplanting the ordinary fire assay of lead. Briefly the method consists in first obtaining the lead in solution by means of nitric acid, followed by the separation of the lead from solution by means of sulphuric acid, which precipitates the lead as sulphate. Following this the lead sulphate is dissolved in a solution of ammonium acetate and acetic acid. The amount of lead present is then determined by titration with a standard solution of ammonium molybdate.

Weigh out one Gm. of the finely pulverized ore and digest over the hot plate with 10 c.c. of concentrated nitric acid until decomposed, using more acid if necessary. Use a 150 c.c. beaker for this. Add 10 c.c. of concentrated sulphuric acid, and evaporate until white fumes appear. Allow to cool, dilute to 75 c.c. with distilled water and warm again on the hot plate until all soluble salts seem to have been brought into

solution. Allow to settle, then pour the solution onto a filter, leaving as much of the residue as possible in the beaker. Add to this residue in the beaker 20 c.c. diluted sulphuric acid, stirring the contents in the meantime, then allow to settle again, and pour off the solution from the top into the funnel, which was used before. Repeat this process twice more with 20 c.c. dilute sulphuric acid, then once with 10 c.c. of distilled water. When this last wash has been poured off through the funnel, add to the residue in the beaker 20 c.c. of strong solution of ammonium acetate and warm over the hot plate until the precipitate is brought into solution. Pour this solution over the filtrate until the precipitate retained by it is also dissolved, receiving the filtered solution in a clean 400 c.c. beaker. Wash the filter thoroughly. Add to the filtrate and washings 5 c.c. of dilute acetic acid, then dilute to 200 c.c., heat strongly to boiling, and finally add to this hot solution the ammonium molybdate from a burette until a drop of the solution when brought into contact with a drop of tannin solution on a porcelain plate gives a faint yellow color. The lead value of the molybdate solution will be known from the standardization against pure lead foil. Supposing that 1 c.c. of this molybdate solution is equivalent to .01 Gm. of lead, then when 1 Gm. of ore is taken each c.c. of molybdate used represents $.01 \div 1$, or 1 per cent lead in the sample taken.

"B" Standardization of the Ammonium Molybdate Solution.—Weigh out .25 Gm. of pure lead foil in a 100 c.c. beaker, add 10 c.c. of dilute nitric acid, and warm until dissolved, then add 10 c.c. of sulphuric acid and evaporate until white fumes begin to appear. Allow to cool, then dilute to 75 c.c., allow the precipitate to settle and decant through a small filter. Wash the precipitate as described in paragraph *"A"* three times with dilute sulphuric acid, and once with pure water, aiming to keep the main part of the precipitate in the beaker. Now add to the beaker 20 c.c. of strong solution of ammonium acetate, as in paragraph *"A,"* and warm until the precipitate is dissolved. The remainder of the process is just as described in the determination of the lead in the ore. The ammonium molybdate solution should contain 9 Gm. of ammonium molybdate per liter, and 1 c.c. should precipitate .01 Gm. of lead. To illustrate, suppose that for the .25 Gm. of lead which we took, it requires 23.5 c.c. of the molybdate solution to give the required color with the tannin indicator, then 1 c.c. of the solution will represent .25 ÷ 23.5, or .0107 Gm. of lead.

"C" Preparation of Tannin Indicator.—Dissolve 5 Gm. pure tannic acid in 150 c.c. water. This solution should be made up fresh every day or so, to prevent deterioration. In case only a few lead assays are to be made, the quantity of indicator to be prepared of

course may be reduced. When a drop of this indicator is placed on a white porcelain plate, and a drop of molybdate added to it, there is immediately formed a yellow coloration, and from this fact we can at once ascertain when there is an excess of molybdate present, or in other words can ascertain when we have added sufficient of the molybdate to react with all the lead present.

CHAPTER XV.

DISTILLED WATER.

"*A*" The Desirability of Using Distilled Water.—"*B*" How to Purify Water for Laboratory Purposes without Distilling.—"*C*" A Convenient Form of Apparatus for Distilling Water.

"*A*" *The Desirability of Using Distilled Water.*—In all operations in assaying and chemical analysis it is desirable to use distilled water. There are very few places where the assayer cannot procure distilled water.

"*B*" *How to Purify Water for Laboratory Purposes without Distilling.*—If it is necessary to use ordinary water, add a few drops of nitrate of silver solution made by dissolving a small piece of chemically pure silver foil in a little chemically pure nitric acid. This wash may be prepared in a large glass bottle. Upon the first addition of the silver nitrate solution to undistilled water a milky cloud will appear in the water, which is silver chloride. Shake the bottle and allow this cloud to settle, then add a few more drops of the silver nitrate solution. If no further milky cloud is produced upon the addition of the silver nitrate solution, all the chlorine in the water has been precipitated as silver chloride. The water may now be decanted off into another stoppered container and is ready for use.

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"C" A Convenient Form of Apparatus for Distilling Water.—A convenient apparatus for making distilled water may be obtained from most laboratory supply houses. The still illustrated (Fig. 56) has a capacity of about 1000 c.c. per hour.

Fig. 56—Water Still

CHAPTER XVI.

MERCURY DETERMINATION BY DISTILLATION.

"*A*" Usual Charge.—"*B*" Apparatus Required.—"*C*" Method of Making Determination.—"*D*" Estimating Results.—"*E*" Cleaning of Apparatus after Each Determination.

"*A*" *Usual Charge.*—This assay is one of distillation and is very accurate. Mix 1 gram of the pulped ore with 2.5 grams of iron filings.

"*B*" *Apparatus Required.*—Place in a porcelain crucible of sufficient size (diameter of about 1⅝ inches and having the same height). Cover the charged crucible with a sheet gold cover extending over the edge of the crucible. The edge of the cover should be flanged up all around like a tin pan, to contain water for keeping the gold cover cool so that the volatilized mercury will condense and adhere to the under side of the cover.

"*C*" *Method of Making Determination.*—Set the charged and covered crucible in a ring stand, and apply heat from a Bunsen burner or an alcohol lamp. Apply the flame only to the bottom of the crucible, and do not let it play on the sides. The distillation takes from fifteen to thirty minutes. Keep the cover cool during the distillation by adding cold water sufficient to equalize the evaporation. Before covering the cru-

cible preparatory to commencing the operation carefully clean the cover and weigh accurately.

"D" Estimating Results.—After the distillation is completed dry the cover of moisture, using care not to rub any of the adhering mercury from the under side of the cover. Carefully weigh the cover with its adhering mercury. The difference in the weight of the cover before and after the distillation is the weight of the mercury. The percentage of the mercury is the weight of the mercury divided by the weight of the ore from which it was distilled. For example: weight of cover before distillation 5 grams; weight of cover after distillation 5.1 grams. The difference, 0.1 gram, is mercury. If 1 gram of ore was treated, $0.1 \div 1 \times 100 = 10$, the percentage of mercury.

A pulp balance sensitive to 1 milligram will disclose ordinary commercial percentages. Should 1 gram of ore yield 1 milligram of mercury, the percentage would be 1/10 of 1 per cent. Should the operator possess no balance more sensitive than this, treat more ore that more mercury may be obtained to weigh.

"E" Cleaning of Apparatus after Each Determination.—The mercury may readily be removed preparatory to another determination by heating the cover to a low red heat either in the muffle or in the flame of a Bunsen burner or alcohol lamp. A silver

cover may be substituted if a gold cover cannot be procured. CAUTION: Do not handle the under side of the cover with greasy hands. Grease may be removed by washing the cover with a solution of potassium cyanide.

CHAPTER XVII.

WHITTON'S METHOD OF MERCURY DETERMINATIONS.

"*A*" The Occurrence of Mercury.—"*B*" Various Methods of Determination.—"*C*" Description of Whitton's Apparatus.—"*D*" Method of Performing Assay.—"*E*" Estimation of Results.

"*A*" *The Occurrence of Mercury.*—Mercury occurs in nature in sufficient quantity to be of commercial importance in but two forms. It is most abundant as cinnabar, the sulphide (HgS) containing 86.2 per cent mercury; and secondly as native mercury.

Modern methods of working the ore allow the treatment of ores carrying as low as 0.35 per cent at a profit. The determination of the mercury content in such low-grade ores with sufficient accuracy, within about 1 per cent of the mercury present, offers quite a problem to the chemist.

"*B*" *Various Methods of Determination.*—Methods for the determination of mercury in ores may be classed under five heads as follows:

(1) Gravimetric.
(2) Volumetric.
(3) Electrolytic.
(4) Distillation.
(5) Distillation-amalgamation.

It may be said of all wet determinations of mercury

that they require quite delicate manipulation, and are neither rapid nor accurate enough to satisfy the demands of technical work.

The volumetric methods are mostly complicated, and possess no advantages as regards accuracy or time. As they require the absence of certain metals they are not generally available.

The electrolytic method is satisfactory, except on quite low-grade ores.

The distillation assay, often called the fire assay of mercury, requires delicate manipulation, and to get good results elaborate apparatus. As ordinarily performed it is far from accurate, giving results much too low, especially on low-grade ores. Much difficulty is encountered in effectually sealing all joints of the apparatus.

The utilization of very low-grade ores has generally resulted in the discarding of all other methods in favor of the distillation-amalgamation assay, which gives the most accurate results and admits of closer comparisons than the above methods. In this method the mercury is recovered in the form of an amalgam of gold or silver.

The following method is extremely simple, quite accurate, and requires no special apparatus: Prepare a piece of glass tubing about 10 inches long, 5/16″ internal diameter, closed at one end, and bent at an angle of 45 degrees about 2 inches from the closed end.

Introduce into this closed end a weighed amount of ore, and mix with iron filings or lime. See that the tube above the bend is free from dust, etc., and wrap this portion of the tube with a wet cloth for cooling. The lower part of the tube is then heated for 15 minutes, the mercury being volatilized and condensing above the bend. This mercury may now be collected by any appropriate means and weighed.

The Whitton method possesses novel features which render the assay more accurate and reliable, manipulation is simpler, and the time is not lengthened.

"C" Description of Whitton's Apparatus.—The apparatus (Fig. 57) consists of a steel retort with a cover of sheet silver, and above this is a flat bottomed cooling dish of brass, these three essential pieces being clamped tightly together. Thus the distillation is performed in a closed retort, which prevents the escape of mercury vapor, and renders careful regulation of the heat unnecessary. Another important advantage lies in the use of the steel retort. It should be recognized that mercury vapors will condense upon any surface below the boiling point of mercury, 357.82° C., whether that surface be ore with which they will amalgamate or not. The steel retort is a good conductor of heat, and thus all portions of it are readily brought above this temperature, while the foil is kept below this temperature by its contact with

the bottom of the cooling dish; thus the vapor must condense upon the foil, and not upon any other portions of the exposed inner surface of the retort.

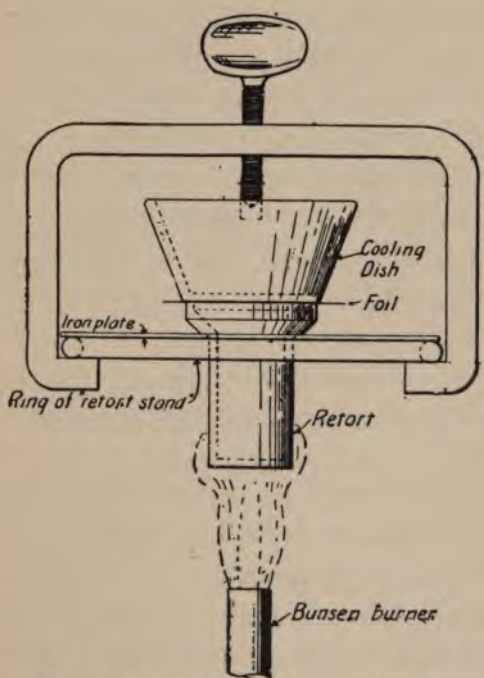


FIG. 57—Apparatus for determining mercury.

Upon the surface of silver exposed in the retort as much as 0.15 gram of mercury may be deposited, but it is preferable to use such quantities of ore that not over 0.05 gram will be deposited, when the amalgam formed adheres firmly to the foil.

As a desulphurizer or flux iron filings are used. The preparation of the filings is important. They should be put through a 50-mesh sieve, washed very thoroughly with alcohol or carbon disulphide to remove grease, and heated for an hour or more in the muffle or upon a hot plate. It is not advisable to have them too fine, and all that will go through an 80-mesh sieve should be discarded if the best results are desired. A blank test with the filings should not increase the weight of a new foil nor discolor it.

"D" Method of Performing Assay.—The assay is conducted as follows: Take from 0.15 to 2 grams of the ore, according to richness, place in the retort, and mix very thoroughly with about 6 grams of the prepared filings, adding 3 grams more as a cover. Weigh a square of foil, and assemble the apparatus, screwing the clamp down firmly. Fill the cooling dish with water, and heat for 17 minutes. If a Bunsen burner is used regulate the heat as follows: have the bottom of the retort about 1¼ inches from the top of the burner. The gas flame should be turned down quite low, and the blue cone should just strike the bottom of the retort while the flame runs up the sides of the retort for about ½ an inch. The tendency of a beginner is to have too high a heat. The water in the cooling dish should come to a boil in six or seven minutes, and should be allowed to boil throughout the assay,

being replaced only once or twice as it boils away. This keeps the foil above the boiling point of water, while below that of mercury; thus no water remains upon the foil at the conclusion of the assay, and desiccation of the foil is unnecessary; it may be weighed almost as soon as it is removed from the retort, as it cools very rapidly. No evidence of over-heating has appeared in many assays; and the close attention of the operator is not necessary during the heating. At the expiration of the 17 minutes' heating, the assay is allowed to cool until it can be handled; this takes about 5 minutes. It is then dismounted and the foil conveyed, under cover to avoid dust, to the balance and weighed.

"E" Estimation of Results.—The increase in weight is due to mercury, and the percentage is readily calculated. The deposit upon the foil should be white in color; if the heat is too long and high the deposit will assume a dark color; this dark deposit is volatile, and is apparently due to oxidation of the mercury. Assays in which this color has appeared are not very reliable; they may vary either way from the correct result, but are generally high.

In the case of ores containing much water, on removing the foil it is occasionally found to have filings upon the deposit, and also is stained a dark color in spots. This is due to a drop of water condensing upon the foil and falling back on to the hot charge in the

retort, where it boils violently and throws up the charge on to the foil. This may be avoided by heating up the charge slowly, or, if very persistent, by the use of a shield above the charge. Probably asbestos wool would be good to use for this purpose.

CHAPTER XVIII.

RETORTING AMALGAM AND MELTING BULLION.

"*A*" Description of Process.—"*B*" Distillation.—"*C*" Modern Retorting Apparatus.—"*D*" Melting Bullion.—"*E*" Flux for Bullion.

It sometimes falls to the lot of the assayer doing commercial work or working in a mining camp to retort the amalgam taken from the plates of a stamp mill and melt the resultant sponge of gold and silver into a bar, and assay the bar so the value of the product may be known.

"*A*" *Description of Process.*—Retorting consists in distilling off the quicksilver from the amalgam and is done in a cast-iron retort (Fig. 58), a vessel having a cover which can be fastened on so tightly that no fumes of mercury escape except by the vapor pipe which leads from the cover to a vessel containing water, where the fumes of quicksilver are condensed to a metallic state. The vapor pipe must either have a water jacket (Fig. 59) surrounding it, through which a small quantity of cold water is continuously passed during the operation, or, if that is not practicable, it can be wrapped with cloth and the cloth soaked with water to keep cool the pipe through which the quicksilver fumes are passing.

The open end of the vapor pipe must be much lower than where it emerges from the cover of the retort, and its open end is sometimes submerged in water during the distilling operation but removed from water as soon as heat is taken from retort, otherwise water rushes back into retort and forms steam and is liable to explode. The joints between the retort and the cover should be luted or filled with a paste of moist wood ashes and common salt or moist bone ash, and the cover must be clamped firmly in place. Before putting the amalgam into the retort, either coat the inside of the retort with plumbago, common white chalk or line with paper. This prevents the remaining bullion from sticking to the retort. The retort should not be filled much over half full of amalgam, as room is required for the vaporized mercury. It is good practice to make the amalgam into several small balls, thus allowing the mercury to vaporize more rapidly.

FIG. 58—Iron retort.

"B" Distillation.—The distillation is performed at

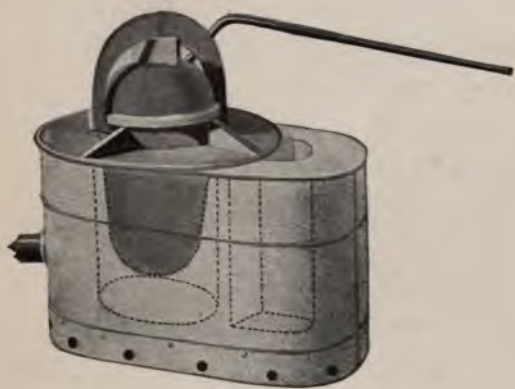
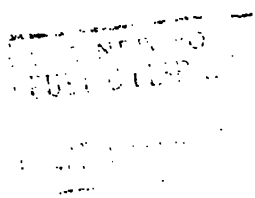


FIG. 60—Gasoline Retorting Outfit



a very low temperature and heat applied very gradually. When the operation is finished the iron retort where exposed to the heat should not be more than at a low red heat. At the beginning when the heat is applied the air is driven out of the retort, which may

FIG. 59—Water jacket threaded to fit retort discharge tube.

be seen by the bubbles arising through the water from the submerged end of the vapor pipe. Soon globules of quicksilver will begin to run out of the vapor pipe into the water. Tap the vapor pipe lightly from time to time to jar out the mercury that may be lodged or clinging to the sides of the pipe. When the iron retort is at a low red heat and no more globules of mercury come out of the vapor pipe, it is safe to assume that the operation is completed.

FIG. 61—Iron retort plate.

"C" Modern Retorting Apparatus.—Retorting is most conveniently done in a gasoline bullion furnace (Fig. 60). The furnace for this purpose should have a cast-iron cover (Fig. 61) which has at its center an opening like those in the top of a stove. The retort should be placed in this hole, supported by the edge of

the hole which should touch the retort at a point about an inch below where the cover joins. The heat applied from a Cary gasoline burner is at all times under control, and may be increased or diminished by opening or closing the needle valve which supplies the gasoline to the burner.

When the mercury ceases to come over, shut off the burner, and when the furnace and retort have cooled off to some extent, remove the cover from the retort while the latter still remains in the iron lid of the furnace. If the retort leaks the operator should be careful not to inhale the fumes of the mercury, as salivation might follow.

"D" Melting Bullion. — When the retort is cool remove the sponge of bullion, and melt it in a graphite crucible of sufficient size (Fig. 62).

Fig. 62—Graphite crucible and cover.

"E" Flux for Bullion.—Borax glass makes the best flux for bullion melting, but it is rather expensive. Soda ash is also a good flux for this purpose. Should the bullion be base or contain much iron it can be fluxed with nitre to good advantage. Use enough flux so that when the bullion is poured into an ingot the top of the bullion will be covered with flux.

The bullion when thoroughly molten should be stirred with a graphite stirring stick (Fig. 63), which

has previously been heated in the furnace so that it will not chill the molten bullion or cause it to splutter. The stirring stick is held with a pair of tongs and the

FIG. 63—Stirring molten bullion with graphite stirring rod.

bullion thoroughly stirred just before pouring. It is necessary to stir the bullion so that the brick may be of uniform fineness throughout in order to obtain a fair sample of the whole when drilling into the bar.

CHAPTER XIX.

CARE OF MUFFLE AND FURNACE.

Cover the bottom of the muffle with bone ash to a depth of about an eighth of an inch. This is to absorb any lead that may spurt into the muffle. Use cupels of good height, as the lead soon passes through a shallow cupel and is absorbed by the floor of the muffle. This is destructive to the muffle, causing the unnecessary expense of replacing and the loss of time attendant thereto.

Heavy roasting dishes and scorifiers when set in the middle of a hot muffle soon cause the bottom to sag. Place the heavy loads as near the sides of the muffle as possible. Keep all the joints between the bricks of the furnace well luted, also lute with fire clay any and all checks that may open in the bricks. The life of the furnace may be long and useful, but its span of life is governed by the condition in which it is kept. An excellent luting for checks and cracks in the bricks may be made of good fire clay and wood ashes in the proportion of 10 parts clay, 1 part wood ashes and 1 part common salt. These parts are measured by the volume of the dry ingredients. The muffle should be luted in with good fire clay with plenty of

long fibre asbestos. The long fibre asbestos prevents the clay from cracking and falling out of the cracks.

Should a large button be cupelled, the cupel containing the button should be set on top of another cupel to prevent the absorbed lead passing into the muffle.

CHAPTER XX.

ACCIDENTS.

As the assayer at a mine is often called upon to relieve suffering in an emergency the following hints may prove helpful.

BURNS.—For dry burns apply freely a saturated solution of bicarbonate of soda, till the pain is allayed.

The following may be used and is also applicable to scalds: Apply a mixture of bicarbonate of soda and lard. If a blister has formed puncture it but leave the skin as a covering if possible. If the burn is of large area apply the lard and soda to one side of a piece of sterilized gauze and cover the wound.

WOUNDS.—Always keep on hand several small unopened packages of sterilized gauze and use each package but once. Some physicians prefer that the wound be wrapped in this and left till they arrive, with no other treatment; circumstances must govern each case, however.

Cleanse your hands by thorough washing with soap and water and rinse in a solution of carbolic acid, 5 per cent, before attempting to treat a wound. If necessary to cleanse it use warm water and soap and finally rinse with weak carbolic acid solution as above.

Finally wrap in sterilized gauze unless other measures, such as bringing the lips together with sticking plaster, are necessary.

In cases of severe bleeding it may be necessary to compress the blood-vessel by means of a knotted handkerchief, the knot laid on the vessel and the ends tied together around the limb and then twisted tight by means of a small stick.

Broken Limbs.—Where a broken limb is suspected always examine the person very carefully before moving him. If a break is found lay a soft cloth on each side of the limb and outside of that a stick, even a cane, and bind all firmly but gently together, then transfer the patient to a stretcher which every mine should possess.

Cyanide Eruption.—This is caused by having the hands and arms in cyanide solution, and may be overcome by bathing the parts affected in a warm bath of water containing sodium chloride and bicarbonate. Another remedy is the application of compound tincture of benzoin, known as Friar's balsam.

Cyanide Poisoning.—The best remedy is the hypodermic injection of a 3 per cent solution of hydrogen peroxide, repeating the injection several times at intervals of four minutes to different parts of the body. At the same time the stomach should be washed out with a 2 per cent solution of the same. Of course this

necessitates the keeping on hand in well-stoppered bottles, a solution of hydrogen peroxide and implies the ability to use a hypodermic syringe.

In case nothing better is at hand, two drops of ammonia may be placed on a lump of sugar and the whole eaten at once. Apply cold water to head and spine, use stimulants and resort to artificial respiration.

In cases of poisoning by the gas get the patient to the fresh air at once and apply ammonia cautiously to the nose. Give a little brandy internally or hypodermically and rub the limbs.

ASPHYXIATION.—If the person has not been chilled lay him on his back, loosen the clothing at the neck and dash cold water forcibly over the head and neck at intervals for half a minute. Dry the face and use artificial breathing by bringing the arms above the head, then down at the sides, and finally bring the elbows together over the chest; repeat this till the patient breathes naturally.

If the person has been chilled put him in a warm bed, use artificial respiration and apply friction to the hands and feet.

In connection with this subject it may be said that Oxone when used in a proper apparatus will not only furnish the oxygen needed for breathing when in a foul atmosphere, but will, by virtue of the caustic soda formed, absorb the carbonic acid formed in the process

of breathing and so permit the air to be breathed over and over again. This will obviate the necessity of keeping compressed oxygen on hand for use in rescue work.

SALIVATION (Mercury Poisoning).—When salivated by the inhalation of mercury fumes, the free use of lime water both as a mouth wash and as a drink will prove beneficial; also the liberal drinking of milk. In acute cases administer a saturated solution of potassium iodide in ten-drop doses three or four times a day.

M. W.

CHAPTER XXI.

OXONE: ITS APPLICATION AND USE IN THE MINE.

The utility which this chemical is destined to find in mining interests prompts us to find room for a few words on it in this treatise.

Oxone is fused sodium peroxide with a fractional percentage of a catalytic substance. The electrically molten substance is cast into molds of various shapes, forming solid pieces of a grayish color, hard, dense, but not brittle. It keeps in sealed tins indefinitely and is a very handy substance for transportation.

In contact with water or only vapor the peroxide decomposes, yielding its full amount of available oxygen in gas form and leaving behind a solution of caustic soda.

$$Na_2O_2 + H_2O = 2NaOH + O$$

This simple process, quite practicable in execution by means of a special generator, recently introduced Oxone into mining laboratories, where the absolute purity of the generated oxygen adds to its importance.

But this, from a miner's point of view, is by far not the main feature of this substance. What interests him is its quality of having carbon dioxide absorption (by caustic soda) and oxygen yield combined into one *unit.*

In the various systems of respirators which are fast, though not fast enough, being developed, in fact which are far from trustworthy perfection, caustic soda or potash is used for carbon dioxide absorption and separately one or two oxygen tanks are carried on the back. This means weight, space, complication and limitation. The use of oxone means entire elimination of the weightier half of the outfit, the oxygen cylinder, and exchange of the other factor, the caustic soda. Or we then have a respirator in which the usual caustic soda does not only absorb CO_2 but at the same time furnishes the required oxygen. As a few pounds of chemical when once used up are easier replaced than an empty oxygen tank, it is clear that we have before us not only a considerable reduction in weight, space, and complication, but that limitation is also deferred.

The reaction in the Oxone respirator is produced by the humidity of the man's breath, similar to above. Bubbles of oxygen and a moist layer of caustic form immediately, the latter then absorbing CO_2, probably first like this:

$$NaOH + CO_2 = NaH + CO_3$$

For further data we have to refer to the mining departments of coal districts and to the paper "Report of Experiments with Fused Sodium Peroxide for the Regeneration of Air in Submarines" by G. F. Brindley

and R. von Foregger, ninth general meeting of the American Electrochemical Society, Ithaca, N. Y., May 1, 2 and 3, 1906.

In our opinion it is a mistake to speak of these respirators most exclusively by the term "Life Saving Apparatus," just as well as it is an error committed by a great many to consider oxygen only from the point of view of its life prolonging capacity when death is near. A respirator, when once a usefully perfected article, should prevent disaster, and help through disaster. We mean by this that when once a respirator enables a workman, without the least embarrassment, to work during four or eight hours in his own sealed up regenerated atmosphere, it will be possible to control the atmosphere which surrounds him in the mine. Instead of pumping air, which favors combustion and explosion, we will be enabled to pump any inert gas, replacing black damp and fire damp.

R. & H. C. Co.

REFERENCE TABLES AND INFORMATION

25600
20
51200

REFERENCE TABLES AND INFORMATION

COMPARISONS AND EQUIVALENTS

TROY WEIGHT.

For weighing precious metals, such as gold, platinum, silver, etc., Troy weights are used exclusively.

The U. S. standard Troy pound was copied in 1827 from the imperial Troy pound of England for the use of the United States Mint, and there deposited. It is standard in air at 62° Fahr., the barometer at 30 inches.

24 grains = 1 pwt.
480 grains = 20 pwts. = 1 oz.
5760 grains = 240 pwts. = 12 ozs. = 1 lb. = 22.816 cu. ins. of distilled water at 62° Fahr.

AVOIRDUPOIS WEIGHT.

For weighing base metals such as lead, antimony, tin, etc., and the weight in general use in trade and commerce in the U. S.

1 drachm =			27.34375 grains Troy.	
16 drachms =	1 oz. =	437.5 grains Troy.		
256 drachms =	16 ozs. =	1 lb. =	1.2153 lb. Troy.	
6400 drachms =	400 ozs. =	25 lbs. =	1 quarter.	
25600 drachms =	1600 ozs. =	100 lbs. =	4 quarters =	1 cwt.
512000 drachms =	32000 ozs. =	2000 lbs. =	80 quarters =	20 cwts. = 1 ton

APOTHECARIES' WEIGHT.

20 grains = 1 scruple.
60 grains = 3 scruples = 1 drachm.
480 grains = 24 scruples = 8 drachms = 1 oz.
5760 grains = 288 scruples = 96 drachms = 12 ozs. = 1 lb.

METRIC, OR FRENCH WEIGHTS.

	Grammes	Troy grs.	Troy ozs.	Troy lbs.	Avoir. ozs.	Avoir. lbs.
1 Milligramme .. =	.001 =	.01543				
1 Centigramme .. =	.01 =	.15432				
1 Decigramme ... =	.1 =	1.5432				
1 Gramme ..... =	1. =	15.432 =	.032 =	.00267 =	.03528 =	.0022047
1 Decagramme .. =	10. =	.....	.321 =	.02679 =	.3528 =	.022046
1 Hectogramme . =	100. =	.....	3.215 =	.26792 =	3.52758 =	.22046
1 Kilogramme ... =	1000. =	.....	32.150 =	2.6792 =	35.2758 =	2.2046
1 Myriagramme . =	10000. =	.....		26.792 =	.....	22.046
1 Quintal ..... =	100000. =	.....		267.92 =	.....	220.46
1 Tonneau ..... =	1000000. =	.....		2679.2 =	.....	2204.6

The unit of the metric system is the gramme = 15.438395 Troy grains, or the weight of 1 c.c. of distilled water at 4° C.

ASSAY TON WEIGHTS.

The assay ton weights is a system made up from a comparison of the Avoirdupois, Troy and Gramme weights, and will be found extremely simple and useful, saving a vast amount of calculation and labor.

The unit of the system is the assay ton (A. T.) = 29.166 grammes. Its derivation will be seen at a glance.

1 lb. Avoirdupois = 7,000 Troy grains.

2,000 lbs. = 1 ton

2,000 × 7,000 = 14,000,000 Troy grains, in one ton Avoirdupois.

480 Troy grains = 1 oz. Troy.

14,000,000 ÷ 480 = 29,166 Troy ozs. in 2,000 lb. Avoirdupois.

There are 29,166 milligrammes in one assay ton (A. T.); hence 2,000 lb. is to 1 A. T., as 1 oz. Troy is to 1 milligramme. Therefore if 1 A. T. of ore assays 1 milligramme of gold or silver, the ton contains 1 ounce Troy.

COMPARISON OF AVOIRDUPOIS, METRIC, TROY AND ASSAY TON WEIGHTS

	Avoir. Ounce	Avoir. Pound	Milligrammes	Centigrammes	Decigrammes	Grammes	Decagrammes
1 Avoir. Oz	1.	.06250	28349.5403	2834.95403	283.495403	28.3495403	2.83495403
1 Avoir. Lb.	16.	1.	453592.6449	45359.26449	4535.926449	453.5926449	45.35926449
1 Milligramme	.00003527394	.00000220462	1.	.1	.01	.001	.0001
1 Centigramme	.0003527394	.0000220462	10.	1.	.1	.01	.001
1 Decigramme	.003527394	.000220462	100.	10.	1.	.1	.01
1 Gramme	.03527394	.00220462	1000.	100.	10.	1.	.1
1 Decagramme	.3527394	.0220462	10000.	1000.	100.	10.	1.
1 Hectagramme	3.527394	.220462	100000.	10000.	1000.	100.	10.
1 Kilogramme	35.27394	2.20462	1000000.	100000.	10000.	1000.	100.
1 Troy Grain	.00228571	.000142857	64.79897	6.479897	.6479897	.06479897	.006479897
1 Troy Pwt.	.0548571	.0034285	1555.1754	155.51754	15.551754	1.5551754	.15551754
1 Troy Ounce	1.0971428	.0685714	31103.495	3110.3495	311.03495	31.103495	3.1103495
1 Troy Pound	13.165714	.822857	373241.9478	37324.19478	3732.419478	373.2419478	37.32419478
1 Assay Ton	1.0288232	.....	.....	.....	.....	29.1666666	.....

	Hectagrammes	Kilogrammes	Troy Grain	Troy Pwt.	Troy Ounce	Troy Pound
1 Avoir. Oz	.283495403	.0283495403	437.5	18.22917	.911458	.07595483
1 Avoir. Lb.	4.535926449	.4585926449	7000.	291.66666	14.583333	1.215277
1 Milligramme	.00001	.000001	.015432349	.0006430145	.000032150727	.00000267922725
1 Centigramme	.0001	.00001	.15432349	.006430145	.00032150727	.0000267922725
1 Decigramme	.001	.0001	1.5432349	.06430145	.0032150727	.000267922725
1 Gramme	.01	.001	15.432349	.6430145	.032150727	.00267922725
1 Decagramme	.1	.01	154.32349	6.430145	.32150727	.0267922725
1 Hectagramme	1.	.1	1543.2349	64.30145	3.2150727	.267922725
1 Kilogramme	10.	1.	15432.349	643.0145	32.150727	2.67922725
1 Troy Grain	.0006479897	.00006479897	1.	.041666	.0020833	.000173611
1 Troy Pwt.	.015551754	.0015551754	24.	1.	.05	.0041666
1 Troy Ounce	.31103495	.031103495	480.	20.	1.	.08333333
1 Troy Pound	3.732419478	.3732419478	5760.	240.	12.	1.
1 Assay Ton	.....	.....	.....	.....	.....	.....

TABLE TO CONVERT METRIC WEIGHTS INTO AVOIRDUPOIS AND TROY WEIGHTS.

As one gramme is equal to 15.432×grains, or .03527 Avoirdupois ounce, or .03215 Troy ounce; to convert:

Grammes	into grains	multiply by 15.432
Centigrammes	into grains	multiply by 0.15432
Milligrammes	into grains	multiply by 0.01543
Kilogrammes	into Avoirdupois ounces	multiply by 35.2739
Grammes	into Avoirdupois ounces	multiply by .03527
Kilogrammes	into Avoirdupois pounds	multiply by 2.2046
Kilogrammes	into Troy ounces	multiply by 32.1507
Grammes	into Troy ounces	multiply by .03215

TABLE TO CONVERT AVOIRDUPOIS AND TROY WEIGHTS INTO METRIC WEIGHTS.

As one grain is equal to 0.0648 and one Avoirdupois ounce is equal to 28.3495 grammes, and one Troy ounce is equal to 31.1035 grammes; to convert:

Grains	into grammes	multiply by 0.0648
Grains	into centigrammes	multiply by 6.4799
Grains	into milligrammes	multiply by 64.799
Avoirdupois ounces	into kilogrammes	multiply by 0.02835
Avoirdupois ounces	into grammes	multiply by 28.3495
Avoirdupois pounds	into kilogrammes	multiply by 0.4536
Troy ounces	into kilogrammes	multiply by 0.0311
Troy ounces	into grammes	multiply by 31.1035

LINEAR MEASURE, U. S. STANDARD.

The standard unit of the United States and British linear measure is the yard. It was intended to be exactly the same for both countries, but in reality the United States' yard exceeds the British standard by .00087 inch. The actual standard of length for the United States is a brass scale 82 inches long prepared for the Coast Survey and deposited in the office of Weights and Measures at the U. S. Treasury Department, Washington. The yard is between the 27th and 63d inches of this scale. The temperature at which this scale is designed to be standard, and at which it is used in the U. S. Coast Survey, is 62° Fahrenheit.

Inches	Foot	Yard	Fathom	Perch	Furlong	Mile	League
12 =	1.						
36 =	3. =	1.					
72 =	6. =	2. =	1.				
198 =	16.5 =	5.5 =	2.75 =	1			
7920 =	660. =	220. =	110. =	40 =	1		
63360 =	5280. =	1760. =	880. =	320 =	8 =	1	
190080 =	15840. =	5280. =	2640. =	960 =	24 =	3 =	1

LINEAR MEASURE, METRIC.

	Metre	U. S. ins.	Feet	Yards	Miles
1 Millimetre.... =	.001 =	.03937 =	.00328		
1 Centimetre... =	.01 =	.3937 =	.0328		
1 Decimetre.... =	.1 =	3.937 =	.32808 =	.10936	
1 Metre..... =	1. =	39.3704 =	3.2808 =	1.0936	
1 Decametre ... =	10. =	393.704 =	32.808 =	10.936	Miles
1 Hectometre .. =	100. =	.....	328.08 =	109.36 =	.0621375
1 Kilometre.... =	1000. =	.....	3280.8 =	1093.6 =	.621375
1 Myriametre .. =	10000. =	.....	32808. =	10936. =	6.21375

TABLE TO CONVERT U. S. LINEAR MEASURE INTO METRIC LINEAR MEASURE.

As one inch is equal to 0.0254 metres; to convert:

Inches.....into metres.....multiply by 0.0254
Inches.....into centimetres.....multiply by 2.5399
Inches.....into millimetres.....multiply by 25.3997

TABLE TO CONVERT METRIC LINEAR MEASURE INTO U. S. LINEAR MEASURE.

As one metre is equal to 39.370 inches; to convert:

Metres.....into inches.....multiply by 39.370
Centimetres.....into inches.....multiply by 0.3937
Millimetres.....into inches.....multiply by 0.03937

CUBIC MEASURE, U. S. STANDARD.

1,728 cubic inches = 1 cubic foot
46,656 cubic inches = 27 cubic feet = 1 cubic yard.

A cubic foot of water weighs 62½ pounds, and contains 1,728 cubic inches, or 7½ gallons.

CUBIC MEASURE, METRIC.

	Cu. metres	U. S. cu. ins.			
1 Cubic Centimetre	= .000001	= .061025			
1 Cubic Decimetre	= .001	= 61.025	U. S. cu. ft.		U. S
1 Centistere	= .01	= 610.25	= .353156		cu. yds.
1 Decistere	= .1	= 6102.5	= 3.53156	=	.1308
1 Stere	= 1.	=	35.3156	=	1.3080
1 Decastere	= 10.	=	353.156	=	13.080
1 Hectostere	= 100.	=	3531.56	=	130.80

SQUARE MEASURE, U. S. STANDARD.

Inches	Foot	Yard	Perch	
144 =	1.			
1296 =	9. =	1.		
39204 =	272.25 =	30.25 =	1	
1568160 =	10890. =	1210. =	40	Acre
6272640 =	43560. =	4840. =	160 =	1

An acre is 69.5701 yards square; or 208.710321 feet square.

SQUARE MEASURE, METRIC.

	Sq. metres	U. S. sq. in.	Sq. feet	Sq. yards	
1 Sq. Centimetre	= .0001	= .155			
1 Sq. Decimetre	= .01	= 15.5 =	.10764 =	.01196	Acres
1 Centiare	= 1.	= 1550.03 =	10.764 =	1.196	= .00024
1 Are	= 100.	= 155003. =	1076.4 =	119.6	= .0247
1 Hectare	= 10000.	=	107641. =	11960.	= 2.47

DRY MEASURE, U. S. STANDARD.

Bushel	Pecks	Gallons	Quarts	Pints	
1 =	4 =	8 =	32 =	64	Cu. Ins.
	1 =	2 =	8 =	16 =	537.6
		1 =	4 =	8 =	268.8
			1 =	2 =	67.2
				1 =	33.6

NOTE.—The standard U. S. bushel is the Winchester bushel, which is in cylinder form, 18½ inches diameter and 8 inches deep, and contains 2,150.42 cubic inches.

The English Imperial bushel = { 2218.192 cubic inches; 1.03152 U. S. bushels.

The English Quarter = { 8 Imperial bushels; 8¼ (nearly) U. S. bushels; 10.2694 cubic feet.

DRY MEASURE, METRIC.

(In the metric system the dry and liquid measures are the same.)

	Litres	U. S. cu. ins.	U. S. dry
1 Millilitre ..... =	.001	= .061	= .0018 pint.
1 Centilitre ..... =	.01	= .61	= .018 pint.
1 Decilitre ..... =	.1	= 6.1	= .18 pint.
1 Litre ..... =	1.	= 61.02	= 1.8 pints.
1 Decalitre ..... =	10.	= 610.16	= 9.08 quarts.
		U. S. cu. ft.	
1 Hectolitre ..... =	100.	= 3.531	= 2.837 bushels.
1 Kilolitre ..... =	1000.	= 35.31	= 28.378 bushels.
1 Myrialitre ..... =	10000.	= 353.1	= 283.7 bushels.

LIQUID OR WINE MEASURE, U. S. STANDARD.

NOTE.—The standard unit of liquid measure adopted by the U. S. government is the Winchester wine gallon, which contains 231 cubic inches, and holds 8.339 pounds Avoirdupois of distilled water, at its maximum density weighed in air, the barometer being at 30 inches.

Tun	Pipe	H'head	Gals.	Quarts	Pints	Gills		
1 =	2 =	4 =	252 =	1008 =	2016 =	8064		
	1 =	2 =	126 =	504 =	1008 =	4032		
		1 =	63 =	252 =	504 =	2016	Cu. ins.	Cu. cm.
			1 =	4 =	8 =	32 =	231.	= 3785.00
				1 =	2 =	8 =	57.75	= 946.22
					1 =	4 =	28.875	= 473.11

A gallon of water (U. S. standard) weighs 8⅓ pounds, and contains 231 cubic inches.

DIMENSIONS OF CYLINDERS, HOLDING APPROXIMATELY BELOW NAMED. U. S. STANDARD MEASURES.

	Dia.	Height		
A cylinder	1¼ —	3	contains approximately 1 gill	U. S. standard.
A cylinder	2¼ —	3⅝	contains approximately ¼ pint	U. S. standard.
A cylinder	3½ —	3	contains approximately 1 pint	U. S. standard.
A cylinder	3½ —	6	contains approximately 1 quart	U. S. standard.
A cylinder	7 —	6	contains approximately 1 gallon	U. S. standard.
A cylinder	14 —	12	contains approximately 8 gallons	U. S. standard.
A cylinder	14 —	15	contains approximately 10 gallons	U. S. standard.

LIQUID OR WINE MEASURE, METRIC.

In the metric system the liquid and dry measures are the same.

	Litres	U.S. cu. ins.	U.S.	
1 Millilitre .... =	.001 =	.061 =	.00845	gill.
1 Centilitre ... =	.01 =	.61 =	.0845	gill.
1 Decilitre .... =	.1 =	6.1 =	.845	gill = .2113 pints.
1 Litre ..... =	1. =	61.02 =	2.113	pints = 1.056 quarts.
1 Decalitre.... =	10. =	610.16 =	2.641	gallons.
		U.S cu. ft.		
1 Hectolitre... =	100. =	3.531 =	26.417	gallons.
1 Kilolitre .... =	1000. =	35.31 =	264.17	gallons.
1 Myrialitre... =	10000. =	353.1 =	2641.7	gallons.

LIQUID MEASURE, APOTHECARY.

Gal.	Pts.	Ozs.	Drachms	Mins.	Cu. ins.	Grains of water	Cu. cm.
1 =	8 =	128 =	1024 =	61440 =	231. =	58328.886 =	3785.00
	1 =	16 =	128 =	7680 =	28.875 =	7291.1107 =	473.11
		1 =	8 =	480 =	1.8047 =	455.6944 =	29.57
			1 =	60 =	0.2256 =	56.9618 =	3.70

TABLE TO CONVERT U. S. LIQUID MEASURE INTO METRIC LIQUID MEASURE.

As one U. S. liquid ounce is equal to 29.572 cubic centimetres and one pint is equal to 0.4731 litres; to convert:

Pints .....into litres .....multiply by 0.4731
Fluid ounces.....into cubic centimetres.....multiply by 29.572

TABLE TO CONVERT METRIC LIQUID MEASURE INTO U. S. LIQUID MEASURE.

As one litre or 1000 c.c. is equal to 33.8149 fluid ounces; to convert:

Litres .....into fluid ounces.....multiply by 33.815
Cubic centimetres .....into fluid ounces.....multiply by 0.0338
Litres .....into pints.....multiply by 2.113

COMPARISON OF VARIOUS LIQUID MEASURES.

		Grains of water at 62° F.	Cubic centimetre
English Imperial	Gallon = 277.274 cu. ins.	= 70,000.00	= 4,543.000
Wine or Winchester	Gallon = 231.000 cu. ins.	= 58,318.00	= 3,785.200
Corn	Gallon = 268.000 cu. ins.	= 67,861.00	= 4,402.900
Ale	Gallon = 282.000 cu. ins.	= 71,193.40	= 4,619.200

1 cu. ft. = 283.15 c.c.
1 cu. inch = 16.38 c.c.
0.061027 cu. inch = 1 c.c.

PHYSICAL CONSTANTS OF VARIOUS METALS

Metals	Symbol	At. Weight O=16	Specific Gravity	Specific Heat	Melting Pts Deg. C.
Aluminum	Al	27.1	2.56	0.212	625
Antimony	Sb	120.2	6.71	0.051	432
Arsenic	As	75.0	5.67	0.081	
Barium	Ba	137.4	3.75	0.047	1200
Bismuth	Bi	208.5	9.80	0.031	268
Cadmium	Cd	112.4	8.60	0.057	320
Cæsium	Cs	132.9	1.88	.....	26
Calcium	Ca	40.1	1.57	0.170	
Chromium	Cr	52.1	6.80	0.120	1515
Cobalt	Co	59.0	8.50	0.110	1500
Copper	Cu	63.6	8.82	0.094	1054
Didymium	Di	.....	6.54	0.046	
Glucinum	Gl	9.1	2.07	0.580	
Gold	Au	197.2	19.32	0.032	1045
Indium	In	115.0	7.42	0.057	176
Iridium	Ir	193.0	22.42	0.033	1950
Iron, wrought	Fe	55.9	7.86	0.110	1600
Lanthanum	La	138.9	6.20	0.045	
Lead	Pb	206.9	11.37	0.031	326
Lithium	Li	7.03	0.59	0.941	180
Magnesium	Mg	24.36	1.74	0.250	750

PHYSICAL CONSTANTS OF VARIOUS METALS—*Continued*

Metals	Symbol	At. Weight O=16	Special Gravity	Specific Heat	Melting Pts Deg. C.
Manganese	Mn	55.0	8.00	0.120	1245
Mercury	Hg	200.0	13.59	0.032	39.5
Molybdenum	Mo	96.0	8.60	0.072	
Nickel	Ni	58.7	8.80	0.110	1484
Niobium	Nb	.....	6.27		
Osmium	Os	191.0	22.48	0.031	2500
Palladium	Pd	106.5	11.50	0.059	1587
Platinum	Pt	194.8	21.50	0.033	1780
Potassium	K	39.15	0.87	0.170	62
Rhodium	Rh	103.0	12.10	0.058	2000
Rubidium	Rb	85.5	1.52	0.077	38
Ruthenium	Ru	101.7	12.26	0.061	2000
Silver	Ag	107.93	10.53	0.056	961
Sodium	Na	23.05	0.97	0.290	95
Steel	...	.....	.....	.....	1808
Strontium	Sr	87.6	2.54	0.074	
Tantalum	Ta	183.0	10.80		
Tellurium	Te	127.6	6.25	0.047	525
Thallium	Tl	204.1	11.85	0.034	288
Thorium	Th	232.5	7.7	0.028	
Tin	Sn	119.0	7.29	0.056	232
Titanium	Ti	48.1	.....	0.130	3000
Tungsten	W	184.0	19.10	0.033	1700
Uranium	U	238.5	18.70	0.028	
Vanadium	V	51.2	5.50		
Zinc	Zn	65.4	7.15	0.094	419
Zirconium	Zr	90.6	4.15	0.066	

EXPANSION OF METALS THROUGH HEAT

Bodies	Expansion in 0° to 100° C.	
	Decimals	Fractions
Lead	0.002848	1–351
Iron, wrought	0.001167	1–856
Iron, cast	0.001110	1–901
Glass, white	0.000861	1–1161
Gold	0.001552	1–645
Copper	0.001717	1–582
Marmor (Marble of Carrara)	0.000849	1–1178
Brass	0.001920	1–521
Platinum	0.000856	1–1167
Sandstone	0.001174	1–852
Silver	0.001909	1–524
Steel, hardened	0.001225	1–816
Steel, soft	0.001079	1–926
Zinc, rolled	0.003331	1–302
Zinc, cast	0.002987	1–336

TABLE OF HEATING DEGREES

	C.	F.
Red ..... commences at	525°	955°
Dark Red ..... commences at	700°	1292°
Cherry Red ..... commences at	850°	1562°
Light Red ..... commences at	900°	1652°
Yellow ..... commences at	1100°	2012°
White ..... commences at	1300°	2372°
Full White ..... commences at	1500°	2732°

TABLE FOR ESTIMATING THE VALUE OF SILVER

PER TROY OUNCE AT DIFFERENT DEGREES OF FINENESS, BASED $0.50 PER OUNCE 1000 FINE

To find the present market value of silver at any given time, add 2% for every 1c above 50c. Example: To estimate the value of 1 ounce of silver 750 fine, presuming the market value of silver is 63c per ounce for silver 1000 fine, which is 13 cents, or 26% above the computed value in table below, thus: One ounce of silver 750 fine is worth $37\frac{1}{2}$c + 26% = $47\frac{1}{2}$c.

Fine	$	Cents	Fine	$	Cents
10		00.50	340		17
20		01	350		17.50
30		01.50	360		18
40		02	370		18.50
50		02.50	380		19
60		03	390		19.50
70		03.50	400		20
80		04	410		20.50
90		04.50	420		21
100		05	430		21.50
110		05.50	440		22
120		06	450		22.50
130		06.50	460		23
140		07	470		23.50
150		07.50	480		24
160		08	490		24.50
170		08.50	500		25
180		09	510		25.50
190		09.50	520		26
200		10	530		26.50
210		10.50	540		27
220		11	550		27.50
230		11.50	560		28
240		12	570		28.50
250		12.50	580		29
260		13	590		29.50
270		13.50	600		30
280		14	610		30.50
290		14.50	620		31
300		15	630		31.50
310		15.50	640		32
320		16	650		32.50
330		16.50	660		33

TABLE FOR ESTIMATING THE VALUE OF SILVER

PER TROY OUNCE AT DIFFERENT DEGREES OF FINENESS, BASED $0.50 PER OUNCE 1000 FINE—*Continued*

Fine	$	Cents	Fine	$	Cents
670		33.50	840		42
680		34	850		42.50
690		34.50	860		43
700		35	870		43.50
710		35.50	880		44
720		36	890		44.50
730		36.50	900		45
740		37	910		45.50
750		37.50	920		46
760		38	930		46.50
770		38.50	940		47
780		39	950		47.50
790		39.50	960		48
800		40	970		48.50
810		40.50	980		49
820		41	990		49.50
830		41.50	1000		50

TABLE FOR ESTIMATING THE VALUE OF GOLD

PER TROY OUNCE AT DIFFERENT DEGREES OF FINENESS, BASED ON $20.6718 PER OUNCE FOR 1000 FINE

Fine	$	Cents	Fine	$	Cents
10		20.67	130	2	68.73
20		41.34	140	2	89.41
30		62.02	150	3	10.08
40		82.69	160	3	30.75
50	1	03.36	170	3	51.42
60	1	24.03	180	3	72.09
70	1	44.70	190	3	92.76
80	1	65.37	200	4	13.44
90	1	86.05	210	4	34.11
100	2	06.72	220	4	54.78
110	2	27.39	230	4	75.45
120	2	48.06	240	4	96.12

TABLE FOR ESTIMATING THE VALUE OF GOLD

PER TROY OUNCE AT DIFFERENT DEGREES OF FINENESS, BASED ON $20.6718 PER OUNCE FOR 1000 FINE—*Continued*

Fine	$	Cents	Fine	$	Cents
250	5	16.80	630	13	02.33
260	5	37.47	640	13	23.00
270	5	58.14	650	13	43.67
280	5	78.81	660	13	64.34
290	5	99.48	670	13	85.01
300	6	20.16	680	14	05.68
310	6	40.83	690	14	26.36
320	6	61.50	700	14	47.03
330	6	82.17	710	14	67.70
340	7	02.84	720	14	88.37
350	7	23.51	730	15	09.04
360	7	44.19	740	15	29.72
370	7	64.86	750	15	50.39
380	7	85.53	760	15	71.06
390	8	06.20	770	15	91.73
400	8	26.87	780	16	12.40
410	8	47.55	790	16	33.07
420	8	68.22	800	16	53.75
430	8	88.89	810	16	74.42
440	9	09.56	820	16	95.09
450	9	30.23	830	17	15.76
460	9	50.90	840	17	36.43
470	9	71.58	850	17	57.11
480	9	92.25	860	17	77.78
490	10	12.92	870	17	98.45
500	10	33.59	880	18	19.12
510	10	54.26	890	18	39.79
520	10	74.94	900	18	60.46
530	10	95.61	910	18	81.14
540	11	16.28	920	19	01.81
550	11	36.95	930	19	22.48
560	11	57.62	940	19	43.15
570	11	78.29	950	19	63.82
580	11	98.97	960	19	84.50
590	12	19.64	970	20	05.17
600	12	40.31	980	20	25.84
610	12	60.98	990	20	46.51
620	12	81.65	1000	20	67.18

PROSPECTOR'S GOLD TABLE

FOR DETERMINING THE VALUE OF FREE GOLD PER TON (2,000 lbs.) OF QUARTZ OR CUBIC YARD OF GRAVEL

The table below furnishes an exceedingly simple method for determining the value of free gold in a ton of gold-bearing quartz, or a cubic yard of auriferous gravel.

Take a sample of four (4) pounds of quartz, pulverize it to the usual fineness for horning; wash it carefully by batea, pan, or other means; amalgamate the gold by the application of quicksilver; volatilize the quicksilver by blow-pipe or otherwise; weigh the resulting button, and the value given in the table opposite such weight will be the value in free gold per ton of 2,000 lbs. of quartz.

Example.—Sample of four lbs. produces button weighing one grain, the fineness of the gold being 830; then the value of one ton of such quartz will be $17.87.

If the sample of four pounds should produce a button weighing, say, four-tenths of a grain (.4) then the value of such quartz would be (830 fine) $7.14 per ton.

Weight washed gold 4 lb. sample. Grains	Fineness 780 Value per oz. $16.12.	Fineness 830 Value per oz. $17.15.	Fineness 875 Value per oz. $18.08.	Fineness 920 Value per oz. $19.01.
.1	$ 1.68	$ 1.78	$ 1.88	$ 1.98
.2	3.36	3.57	3.76	3.96
.3	5.03	5.36	5.65	5.94
.4	6.71	7.14	7.53	7.92
.5	8.40	8.93	9.42	9.90
.6	10.07	10.73	11.30	11.88
.7	11.75	12.51	13.19	13.86
.8	13.43	14.29	15.07	15.84
.9	15.11	16.08	16.95	17.82
1	16.79	17.87	18.84	19.81
2	33.59	35.74	37.68	39.62
3	50.38	53.61	56.52	59.43
4	67.18	71.49	75.36	79.24
5	83.97	89.36	94.20	99.05

GOLD VALUE OF A CUBIC YARD OF GRAVEL

To determine the gold value of a cubic yard of auriferous gravel, the same table can also be used.

Take a sample of sixty (60) pounds of gravel, pulverize it, and carefully wash it by batea, pan or otherwise; amalgamate the gold, volatilize the quicksilver; weigh the button, and in column in table, opposite the weight, will be found the gold value of the cubic yard of gravel.

Example.—Sample of sixty pounds produces button weighing one grain, the fineness of the gold being 780; then the value of one cubic yard of such gravel would be $1.67. This is arrived at by pointing off one point, or dividing the value given in the table by 10.

If the sample of sixty pounds yields a button weighing five-tenths (.5) of a grain, then the value of the gravel would be—gold being 780 fine—$0.84 per cubic yard.

SIMPLE ORE TESTS

The following simple tests will show whether an ore carries any precious metals. Afterwards samples of the rock should be assayed to ascertain the amount of value per ton.

Gold.—Powder; roast if sulphurets are present; grind very fine and wash in pan or spoon; examine with lens; yellow particles not soluble in nitric acid. The color of pure gold is bright yellow, tinged with red. Gold may be distinguished from all other metals or alloys by the following simple traits: It is yellow, malleable, not acted upon by nitric acid.

Silver.—Pure silver is the brightest of metals, of a beautiful white color and rich luster.

Chloride of Silver.—If suspected in a pulp, harshly rub a bright and wet copper cartridge thereon. If a chloride or chloride-bromide of silver, it will whiten the copper. Graphite will thus whiten copper or gold, but can be rubbed off.

Copper.—After roasting the pulp, intimately mix and well knead with a like quantity of salt and candle grease or any other fat, and cast into the fire, when the characteristic colors—first blue, then green—will appear. This test is better made at night.

Galena.—Black zinc blende is often mistaken for galena. The two may be distinguished by the infallible sign: The powder of galena is black; that of blende, brown or yellow.

COMPARISON OF HYDROMETER SCALES OF LIQUIDS HEAVIER THAN WATER

TEMPERATURE 63° F.

Degrees Beamè	Specific gravity	Degrees Beamè	Specific gravity	Degrees Beamè	Specific gravity
0	1.0000	26	1.2153	51	1.5325
1	1.0068	27	1.2254	52	1.5487
2	1.0138	28	1.2357	53	1.5652
3	1.0208	29	1.2462	54	1.5820
4	1.0280	30	1.2569	55	1.5993
5	1.0353	31	1.2677	56	1.6169
6	1.0426	32	1.2788	57	1.6349
7	1.0501	33	1.2901	58	1.6533
8	1.0576	34	1.3015	59	1.6721
9	1.0653	35	1.3131	60	1.6914
10	1.0731	36	1.3250	61	1.7111
11	1.0810	37	1.3370	62	1.7313
12	1.0890	38	1.3494	63	1.7520
13	1.0972	39	1.3619	64	1.7731
14	1.1054	40	1.3746	65	1.7948
15	1.1138	41	1.3876	66	1.8171
16	1.1224	42	1.4009	67	1.8398
17	1.1310	43	1.4143	68	1.8632
18	1.1398	44	1.4281	69	1.8871
19	1.1487	45	1.4421	70	1.9117
20	1.1578	46	1.4564	71	1.9370
21	1.1670	47	1.4710	72	1.9620
22	1.1763	48	1.4860	73	1.9895
23	1.1858	49	1.5012	74	2.0167
24	1.1955	50	1.5167	75	2.0449
25	1.2053				

COMPARISON OF HYDROMETER SCALES OF LIQUIDS LIGHTER THAN WATER

TEMPERATURE 63° F.

Degrees Beamè	Specific gravity	Begrees Beamè	Specific gravity	Degrees Beamè	Specific gravity
10	1.0000	27	0.8957	44	0.8111
11	0.9932	28	0.8902	45	0.8066
12	0.9865	29	0.8848	46	0.8022
13	0.9799	30	0.8795	47	0.7978
14	0.9733	31	0.8742	48	0.7935
15	0.9669	32	0.8690	49	0.7892
16	0.9605	33	0.8639	50	0.7849
17	0.9542	34	0.8588	51	0.7807
18	0.9480	35	0.8538	52	0.7766
19	0.9420	36	0.8488	53	0.7725
20	0.9359	37	0.8439	54	0.7684
21	0.9300	38	0.8391	55	0.7643
22	0.9241	30	0.8343	56	0.7604
23	0.9183	40	0.8295	57	0.7565
24	0.9125	41	0.8248	58	0.7526
25	0.9068	42	0.8202	59	0.7487
26	0.9012	43	0.8156	60	0.7449

COMPARISON OF THERMOMETER SCALES OF CENTIGRADE, FAHRENHEIT AND REAUMUR

C. Water freezes at 0° Water boils at 100° F. Water freezes at 32° Water boils at 212° R. Water freezes at 0° Water boils at 80°

Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.
40	40	32	32^{2}	90	25^{8}
37^{2}	35	29^{7}	35^{0}	95	28
34^{4}	30	27^{5}	37^{8}	100	30^{2}
31^{7}	25	25^{4}	40	104	32
30	22	24	40^{6}	105	32^{5}
28^{9}	20	23^{1}	43^{3}	110	34^{6}
26^{1}	15	20^{9}	46^{1}	115	36^{9}
23^{8}	10	18^{6}	48^{9}	120	39^{1}
20^{6}	5	16^{5}	50	122	40
20	4	16	51^{7}	125	41^{4}
17^{8}	0	14^{2}	54^{4}	130	43^{5}
15^{0}	5	12	57^{2}	135	45^{8}
12^{2}	10	9^{8}	60	140	48
10	14	8	62^{8}	145	50^{2}
9^{4}	15	7^{5}	65^{6}	150	52^{6}
6^{7}	20	5^{4}	68^{3}	155	54^{6}
3^{9}	25	3^{1}	70	158	56
1^{1}	30	0^{9}	71^{1}	160	56^{9}
0	32	0	73^{9}	165	59^{1}
1^{7}	35	1^{4}	76^{7}	170	61^{4}
4^{4}	40	3^{5}	79^{4}	175	63^{5}
7^{2}	45	5^{8}	80	176	64
10	50	8	82^{2}	180	65^{7}
12^{8}	55	10^{2}	85^{0}	185	68
15^{6}	60	12^{5}	87^{8}	190	70^{2}
18^{3}	65	14^{6}	90	194	72
20	68	16	90^{6}	195	72^{5}
21^{1}	70	16^{9}	93^{3}	200	74^{6}
23^{9}	75	19^{1}	96^{1}	205	76^{9}
26^{7}	80	21^{4}	98^{9}	210	79^{1}
29^{4}	85	23^{5}	100	212	80
30	86	24	101^{7}	215	81^{4}

A variety of circumstances arise in which it becomes necessary to convert readings from one scale into those of the others, in which case the following rules are to be observed:

1. To convert C° into F°, multiply by 9, divide the product by 5 and add 32
2. To convert F° into C°, subtract 32, multiply by 5 and divide by 9.
3. To convert R° into F°, multiply by 9, divide by 4 and add 32.
4. To convert F° into R°, subtract 32, multiply by 4 and divide by 9.
5. To convert R° into C°, multiply by 5, and divide by 4.
6. To convert C° into R°, multiply by 4 and divide by 5.

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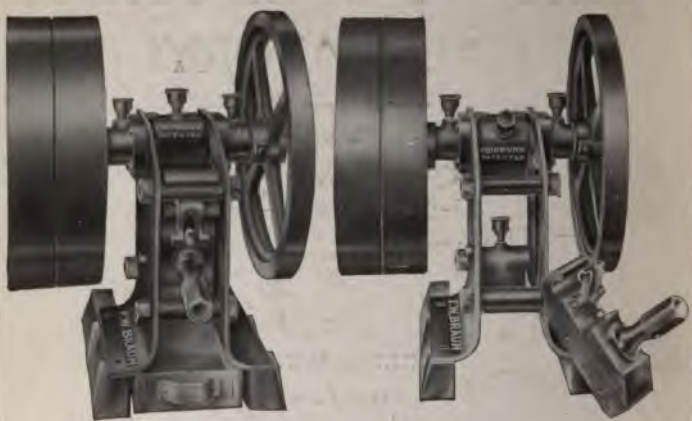
USED IN THE

FOREMOST LABORATORIES

BRAUN IMPROVED CHIPMUNK CRUSHERS



IN the Improved Chipmunk Crusher we offer the ideal laboratory machine. Steel frames are employed, which insures the operator against breakage of any vital parts. The jaws and other fittings are replaceable. The new adjustment consists of a handle fastened to the stationary jaw and fitted with a screw on one end, which can be operated by hand without tools, while the jaw is in place. One turn to the left releases the adjusting plate so it can be raised or lowered, changing from coarse to fine. ¶ The machine is made in two sizes, the smaller one having a capacity of from 300 to 400 pounds per hour, and the larger machine from 1000 to 1500 pounds per hour.

Send for our bulletin covering Crushing and Pulverizing Machines.

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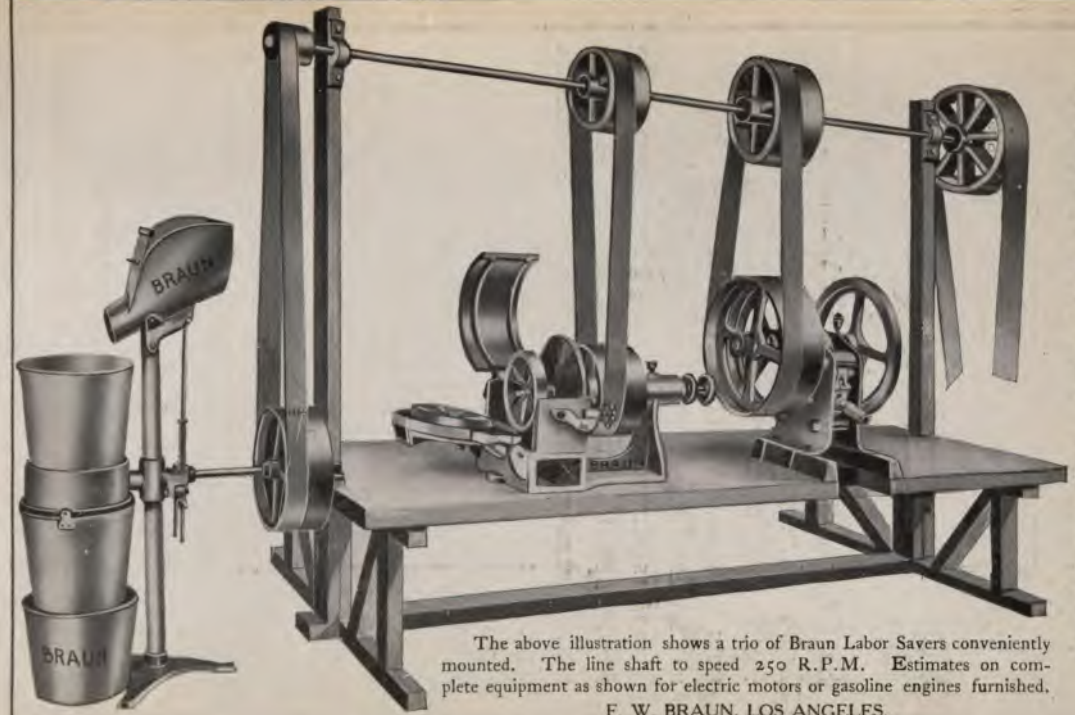

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The above illustration shows a trio of Braun Labor Savers conveniently mounted. The line shaft to speed 250 R.P.M. Estimates on complete equipment as shown for electric motors or gasoline engines furnished.

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Each set of discs is capable of grinding about 5000 to 6000 ordinary samples, or about 2000 to 3000 pounds of medium quartz ore. New sets of discs are furnished as shown in illustration.

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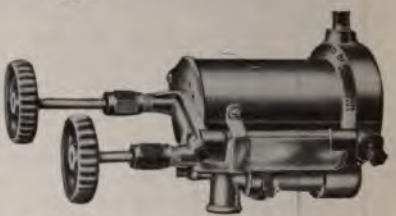

Braun Alcohol Burner.
For alcohol.

Braun Gas Burner.
For illuminating or natural gas.

Marvel Oil Burner.
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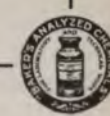

BRAUN MELTING FURNACES

THESE Furnaces are especially designed for use with Cary Hydrocarbon Burners. They are arranged with a special draft outlet, being made on the same principle as a down draft furnace. The fire clay walls are very thick and substantial and will last for many years. They are made in various sizes, the smallest one holding a No. 9 Black Lead Crucible with cover, and the largest one holding a No. 125 Crucible.

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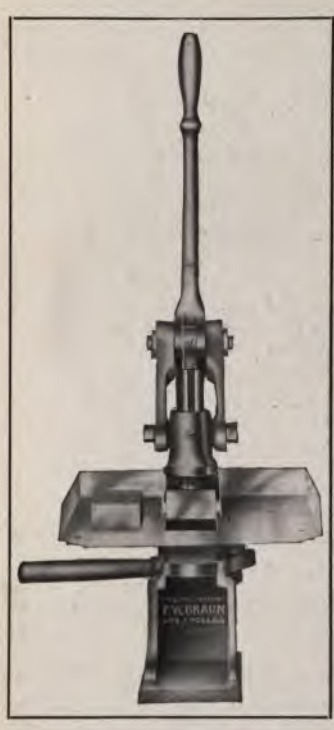
BRAUN BRIQUETTE MACHINE



A SERIES of levers are employed which multiply the applied power twenty times. The pressure is steady, and by adjusting, different degrees of pressure are obtainable. The briquetting partly does away with the expense of calcining, as the product is dried to only 5 per cent moisture. This product is in every way cleaner and safer to handle, and there is no spitting or dusting of the product in the crucible. The capacity of the latter is likewise greatly increased. The machine is made with a square mold and die, 2 ½ x 2 x 1 ½ inches. It makes a clean hard cake. It will handle about 100 pounds per hour. Weight net 45 pounds; packed 75 pounds.

F. W. BRAUN

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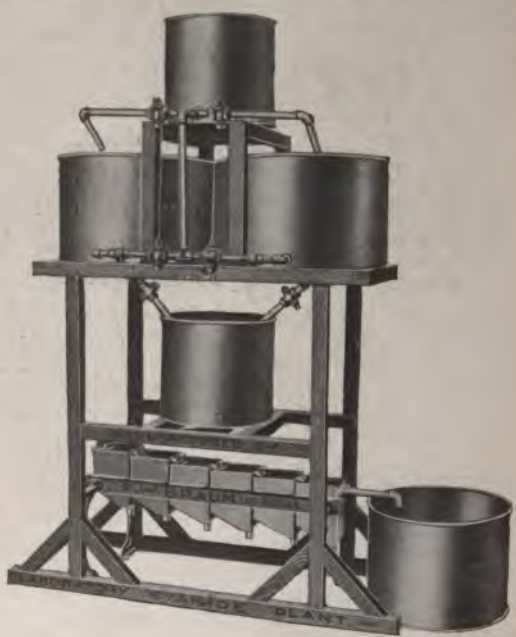
BRAUN CYANIDE PLANT



Laboratory size. Designed for making practical tests of from 100 to 200 pounds in accordance with modern practice. There are six Zinc Boxes arranged in series, it being possible to use any smaller number of units. Measures 69 inches high, 24 inches wide, and 50 inches long. Weighs net 130 pounds; packed for shipment 180 pounds. It is a valuable addition to a metallurgical laboratory. It is furnished complete including filter bottoms for ore tanks.

F. W. BRAUN

Patentee and Manufacturer LOS ANGELES